Arnold Schwarzenegger
Governor

Dairy Power Production Program

DAIRY METHANE DIGESTER SYSTEM PROGRAM EVALUATION REPORT

PIER CONSULTANT REPORT

Prepared For:
California Energy Commission
Public Interest Energy Research Program

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Abstract

This report provides an evaluation of the Dairy Power Production Program (DPPP). The DPPP was initiated to encourage the development of biologically based anaerobic digestion and gasification ("biogas") electricity generation projects on California dairies. The California Energy Commission (CEC), acting under authority of the Legislative enactment in 2001 of SB5X (Section 5(b)(5)(C)(i)), appropriated and encumbered funding for the DPPP. Western United Resource Development, Inc. (WURD) was selected by CEC as the Contractor for this program.

The report includes the following information:

- Background on the program and its purpose
- An overview of anaerobic digestion technologies and electricity conversion
- Utility issues and net metering background and overview
- An overview of installed projects including project locations and major obstacles
- Case studies of each digester project
- Overview of biogas and energy production
- System costs
- Economic performance
- System performance and environmental testing
- Program benefits (e.g. energy production, system performance, economic performance, cost savings and revenue generation)
- Lessons learned

Key words: digester, dairy, power, cow, electrical, methane, methane digester, biogas, biogas production, electricity generation, electricity production, demand charges, utility, energy, energy usage, energy production, manure, net metering, interconnection, system performance, plug flow digester, covered lagoon digester, engine-generator, anaerobic digester.

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Program Overview

The Dairy Power Production Program (DPPP) was initiated to encourage the development of biologically based anaerobic digestion and gasification ("biogas") electricity generation projects on California dairies. Objectives of the grant program included developing commercially proven biogas electricity systems to help California dairies offset the purchase of electricity and provide environmental benefits.

The California Energy Commission had overall responsibility for the program, and set policy and program directions based on the enabling legislation. As the program administrator, WURD had responsibility for day-to-day operation of the program. An advisory group of technical experts was formed to assist CEC and WURD with review of applications and to make recommendations on program content, direction and effectiveness.

The program was designed to provide two types of assistance for qualifying dairy biogas projects: buydown grants that covered a percentage of the capital costs of the proposed biogas system, and incentive payments for generated electricity. In general, buydown grants covered a maximum of up to fifty percent of documented capital costs of the biogas system based on estimated power production, but not to exceed $2,000 per installed kilowatt, whichever was less. Electricity generation incentive payments were based on 5.7 cents per kilowatt-hour of electricity generated by the dairy biogas system paid out over a maximum of five years

Anaerobic Digestion Technologies and Electricity Conversion

Covered Lagoon Digester. A covered lagoon is an earthen lagoon fitted with an impermeable cover that collects biogas as it is produced from flushed manure. The cover is constructed of an industrial fabric that either rests on solid floats laid on the surface of the lagoon or is anchored to the banks. A cover can be placed over the entire lagoon or over only a part. An anaerobic lagoon is best suited for organic wastes with a total solids concentration of 0.5 to 3 percent. Climate is a key factor in the performance of covered lagoons as they are not heated.

Plug Flow Digester. The plug flow digester design is a long linear reactor wherein wastes move slowly through the reactor as a "plug." Plug flow digesters are often built below ground level, with an airtight expandable cover. Manure is collected daily and added to one end of the trough. Each day a new "plug" of organic wastes is added, slowly pushing the other manure down the trough. Plug flow digesters are usually operated with a total solids concentration of 11 to13 percent, at the mesophilic temperature range, and with a hydraulic residence time (HRT) from 20-30 days. Plug flow digesters are usually heated to maintain optimal temperatures.

Complete Mix Digester. Complete mix digesters are engineered tanks located above or below ground. They are compatible with a combination of scraped and flushed manure with solids concentration ranging from 3 to 10 percent. A mix tank is used as a control point to reach optimum solids content prior to introduction into the complete-mix digester. A complete-mix digester is held at a controlled temperature and constant volume.

Energy Conversion. Biogas produced in an anaerobic digester can be converted to electricity through either an internal combustion (IC) engine connected to an electrical generator, or through a turbine connected to an electrical generator. All of the projects in this program use IC engines. There are a number of technologies available to remove some impurities in the biogas in order to lengthen engine life, reduce engine emissions, or to protect emission control systems on the engines. Two of the grant recipients have installed an iron sponge to remove hydrogen sulfide from the biogas.

Utility Issues and Net Metering Background and Overview

Because biogas-to-electricity systems are only recently being constructed on a more widespread scale on California dairies (largely due to the funding provided through DPPP), utility interconnection and net metering provisions were in their infancy during this program. Utilities had to rework their billing structures to implement interconnection and net metering provisions, while dairy owners worked to understand the complexities of generating electricity in parallel with the grid and the best way to maximize their savings due to the on-farm generation of power.

On Site Usage of Generated Power. The largest savings from the generation of power are in the offset of on farm energy needs, with the greatest savings realized when the engine-generator is connected to the main load at the dairy (e.g., the milking parlor, irrigation pumps, etc.). Under this scenario, as electricity is produced, the electricity usage for the dairy is offset (i.e. the amount of electricity imported from the grid is reduced). This reduces the total power purchased from the utility and is valued at the energy rate portion of the full retail rate as specified in the applicable rate schedule. For most of the projects involved, the offset of power cannot be valued at the full retail rate (rate which includes all components such as customer charges, energy charges, demand charges, etc.) due to the fact that demand charges are not subsequently reduced.

Demand Charges. For most projects, maximum demand is established by the measured maximum kilowatt input recorded during any 15-minute metered interval. In most cases, this has substantially reduced the potential savings of on farm use of generated power, as system maintenance or repair necessitates system down time. Demand charges comprised approximately 16%-35% of the total utility bill prior to the generation and utilization of on farm power (i.e. prior to the installation of the digester system). Demand charges for these same projects now comprise 35%-59% of the total utility bill. This shows that the use of on farm power has successfully reduced the energy charge portion of the utility bill but demand charges have not subsequently been reduced even though a majority of the on farm electrical needs are now provided by the farm’s generated power.

Power Purchase Agreements. None of the utility companies with completed digester projects currently offer power purchase agreements for the power produced by each dairy facility. The implementation of power purchase agreements at competitive rates (above the rate they currently enjoy for offset power) could greatly improve the financial feasibility for these projects.

Net Metering. Additional savings can be achieved through the net metering of any excess generated power that is not used on farm. Net metering laws allow electricity generated by a customer to be credited against electricity consumed. Net generation credits are accrued for any time of use during which electrical generation exceeds electrical usage. Savings associated with net metering come from any accrued net generation credits that can be used against unbilled generation charges on the dairy accounts. However, any available generation credit dollars in excess of generation charge dollars remaining at the end of a 12-month period are not paid out by the utility, and are forfeited by the customer. Net generation credits are valued at the generation rate component of the full retail rate. For the ten completed projects, the generation rate averaged $0.03 to $0.05 per kilowatt-hour depending on their applicable rate schedule and utility company.

Overview of Installed Projects

Each completed project is unique in a myriad of ways. Though there are similarities in some instances among the same type of systems, other aspects of the individual dairy operation or employed processes make each project a stand-alone study. The distinctive qualities of each project make side-by-side comparisons difficult to construct. The individual case studies should be referenced for a full understanding of the underlying system or dairy operation.

Of the 55 grant applications received and screened, fourteen were selected for funding, and ten of those completed installation prior to August 2006. The remaining four projects opted not to construct their digester systems due to various fiscal concerns and withdrew from the grant program. Projects installed represent both free stall and drylot dairies with herd sizes ranging from 245 to 6,000 head. The projects are located throughout California, from Marin County to San Diego County. Four of these projects are plug flow digesters, five are covered lagoon systems, and one is a modified-mix plug flow. Six of the systems were new installations, and four were refurbishment or expansion projects. Individual systems installed have an electricity production capacity ranging from 75 kW to over 550 kW. The ten approved projects represent a generating capacity of nearly 2.5 MW and are capable of producing nearly 21.7 million kW hours per year of renewable electricity (assuming operation at 100 percent capacity). During the course of project planning and construction, dairy owners faced a variety of obstacles to completion of their projects. Some of the more common roadblocks included: historically low milk prices, which reduced working capital necessary to pay for project construction; permitting issues and delays; challenges and delays in negotiating interconnection agreements with utilities; the lengthy wait for passage of net metering legislation; and weather related construction delays.

Biogas and Energy Production

Each dairy owner or project manager was faced with unique circumstances in determining the number of hours to run the engine-generator. Most ran their systems at full possible capacity, bringing the system down only for routine maintenance or repairs. Several projects flared a significant amount of the available biogas due to the lack of economic incentive to produce excess power. In any case, it is evident that significant downtime does occur thereby lowering the actual generating capacity.

Biogas production per cow averaged 44.43 cubic feet per day for the covered lagoon digesters and 48.63 cubic feet per day for the plug flow digesters. Electrical generation per cow varied across projects, averaging 1.84 kWh per cow per day for the covered lagoon digester projects and 1.73 kWh per cow per day for the plug flow digester projects. Several factors influence the electricity generation per cow figures, primarily the amount of biogas flared and subsequently not utilized by the engine-generator for power production.

Most systems were designed to produce enough electricity to offset on-farm electrical needs. In most design calculations, downtime for maintenance and repair was factored into the equation when calculating estimated generating capacity. Unfortunately, not all the projects were able to use the generated power on farm. Those who did not utilize the power on farm net metered all their power production. The economic incentive to net meter fell short of the dairy owners' expectations. In most cases, excess generation credits were forfeited to the utility with no compensation. Those dairy owners who used the generated power on farm did enjoy greater returns due to a reduction in electricity purchased from the utility; however, due to the fact that demand charges were not subsequently reduced, their returns fell short of expectations. Even when possible, most projects found no economic incentive to produce surplus electricity and therefore purposely ran their engine-generators at less than capacity, flaring off much of the unused biogas. Six of the projects generated enough electricity to match or exceed their historical on farm usage. Several of the projects were capable of producing additional excess power.

System Costs

The total costs of ten completed projects averaged $1,065,538 for covered lagoon digesters, $930,335 for plug flow digesters and $3,551,448 for the one modified-mix plug flow digester. Cost per cow averaged $585 for covered lagoon digesters, $1,042 for plug flow digesters and $448 for the modified-mix plug flow digester. Cost per kW nameplate capacity averaged $4,654 for covered lagoon digesters, $5,159 for plug flow digesters and $6,308 for the modified-mix plug flow digester. For the covered lagoon digesters, on average, energy conversion and gas handling, as well as general construction, were the largest cost categories, comprising 24% and 28% respectively of the total average costs. For the plug flow digesters, on average, digester and gas production enhancements was the largest cost category, comprising 32% of the total average costs. For the modified mix plug flow system, the digester and gas production enhancement costs was the largest category, comprising nearly 41% of the total costs.

Economic Performance

Estimated savings from generated power varied greatly between projects. The number of cows, biogas production, electrical production, and system performance all played an important role in determining the costs savings for each project. The use of the generated power, either on farm, net metering, or a combination of both also played a vital role in the economic performance. Only a few of the projects benefited from savings due to the use of recovered heat or other revenue streams. Other potential revenue streams exist, and in some cases, plans to implement them are underway. A rather large revenue stream for currently operating methane digester projects across the nation have come from the ability to sell excess generated power back to the utility company. In California, this has not been an option for the completed projects; however, discussions are taking place with utility companies to implement power purchase agreements for these projects. Although plans are still in the preliminary stages, power purchase agreements that provide financial incentive for digesters could be available in the near future. It will be important that these power purchase agreements are offered at competitive rates that exceed those already realized by the offset of power usage on farm. Other possible offset costs or revenue streams may come from the utilization of biogas for heating or cooling purposes or from the sale of byproducts. Several of the projects have reported savings due to the use of recovered heat; however, none have sold their digested solids as byproducts thus far. Another potential revenue stream is through the sale of environmental attributes or carbon credits.

The dramatic increase in the payback years without grant funding compared to that with outside funding highlights the importance of grant funding to the financial feasibility of these projects. Even with substantial grant funding, due to the high costs of constructing the systems combined with the low economic returns for generated power, the simple payback period was longer than anticipated for most projects. For covered lagoon digesters, the payback period with grant funding ranged from 5.1 years up to 10.2 years. For plug flow digesters, the payback range with grant funding was 5.3 years to 48.3 years. Many factors influenced the payback estimates including, but not limited to, overall system costs, system performance and return for generated power. The estimated savings are not reflective of any recent developments or enhanced system performance that took place after the study period. Individual case studies should be referenced for a full discussion.

System Performance and Environmental Testing

During the spring of 2006, a testing campaign was undertaken to collect baseline performance data on the digesters installed. The purpose of the data was to develop a one-time "snapshot" of the operating performance of each digester system, and this effort was not considered to be a comprehensive performance evaluation. This data collection and testing campaign characterized the manure influent and effluent for each system, measured the composition of the biogas, and tested the emissions from the engine generator sets. Manure solids separated before or after digestion were also tested and characterized.

Program Benefits

Producing electricity from livestock wastes is a primary benefit of the program. As noted above, the ten approved projects represent a generating capacity of nearly 2.5 MW and are capable of producing nearly 21.7 million kW hours per year of renewable electricity (assuming operation at 100% capacity). Power production from biogas at dairies is especially beneficial because it can help offset expensive peak electricity. In most cases, the estimated amount of power available from biogas at the dairy exceeds the amount of power used at the dairy. This provides an opportunity for a dairy to offset on farm electrical costs, and, given the development of power purchase agreements, the financial feasibility could be greatly enhanced if excess power could be sold at a reasonable rate to the local utility company. This would result in not only helping the dairies economically, but could preserve electricity generated from fossil fuel-fired peaking units for consumers that have little or no capability to generate electricity.

Dairy owners regularly evaluated system performance during the data collection period. On a scale of one to four, (with 1= poor and 4= excellent), dairy owners rated overall satisfaction with their projects with an average score of 3.1. Extent to which the system helped with reducing water usage and extent to which system helped address electrical needs received the lowest scores. Extent to which the system helped with manure management and odor control received the highest scores across all projects.

The financial feasibility of the completed projects varied greatly depending on the capital costs associated with building the system and the estimated savings attributable to the generation of power, use of recovered heat, or other resulting revenue streams. Savings due to generated power, use of recovered heat or other revenue streams did occur for most all of the projects. However, with the large capital costs needed to build the digester systems combined with the rather low savings, payback periods exceeded original estimates.

Due to the unique characteristics of each project estimated monthly savings varied greatly. Estimated monthly savings ranged from as little as zero during the study period up to $20,000 per month depending on the utilization of power and if additional revenues were generated due to the use of recovered heat, sale of byproducts, etc. In addition to savings explored above, there are other potential revenue streams, including the ability to sell excess generated power back to the utility company. In California, this has not yet been a viable option for the completed projects, but discussions are taking place with utility companies to implement power purchase agreements for these projects. It will be important that these power purchase agreements are offered at competitive rates that exceed those already realized by the offset of power usage on farm.

Other possible offset costs or revenue streams may come from the utilization of biogas for heating or cooling purposes or from the sale of byproducts. Several of the projects have reported savings due to the use of recovered heat however none have sold their digested solids as byproducts thus far. Several dairy owners have expressed their intent to research the possibility. Another potential revenue stream is through the sale of environmental attributes or carbon credits. Recent advertisements from aggregators suggest a potential payment of $0.05 to $0.07 per kilowatt hour for non-energy attributes.

Lessons Learned and Suggestions for Improvements

A long list of suggestions for improvements and individual lessons learned were provided by the dairy owners and/or project managers. Individual responses can be found in the detailed case studies. The list includes, but is not limited to the following:

- Lack of power purchase agreements for generated power reduced the economic feasibility
- Operational expenses are higher than anticipated and electrical generation value is much lower
- Consider all alternatives carefully before moving ahead
- Make sure economics of project work and challenge all assumptions
- Apply for all permits and electrical interconnects early and stay on top of processes

- Grants and subsidies are important
- The system is designed to work as a whole and efficiency of the entire system can be affected by a small problem in one of the components
- Keep system simple and user friendly

For reporting purposes, the distinctive qualities of each project make side-by-side comparisons difficult to construct. Though there are similarities in some instances among the same type of systems, other aspects of the individual dairy operation or employed processes make each project a stand-alone study. For a better understanding of both the unique qualities and commonalities of each project, a review of individual case studies is highly encouraged.

1. Program Overview

Background and Purpose

The Dairy Power Production Program (DPPP) was initiated to encourage the development of biologically based anaerobic digestion and gasification ("biogas") electricity generation projects on California dairies. Objectives of the grant program include developing commercially proven biogas electricity systems that can help California dairies offset the purchase of electricity, and providing environmental benefits by potentially reducing air and ground water pollutants associated with storage and treatment of livestock wastes.

The California Energy Commission (CEC), acting under authority of the Legislative enactment in 2001 of SB5X (Section 5(b)(5)(C)(i)), appropriated and encumbered funding for the DPPP. Western United Resource Development, Inc. (WURD) was selected by CEC as the Contractor for this program.

Program Structure

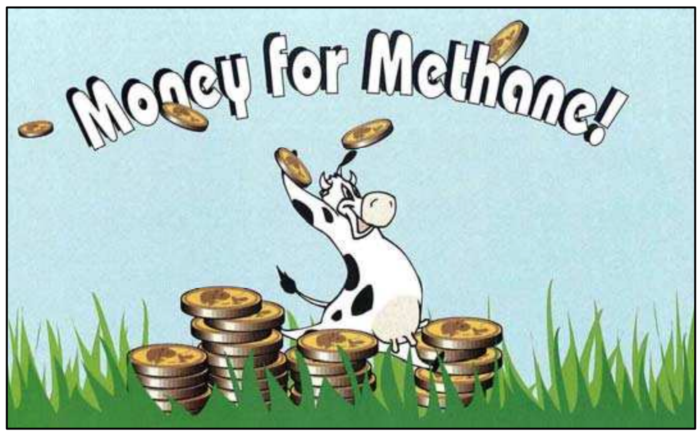
The California Energy Commission had overall responsibility for the program, and set policy and program directions based on the enabling legislation. As the program administrator, WURD had responsibility for day-to-day operation of the program. An advisory group of technical experts was formed to assist CEC and WURD with review of applications and to make recommendations on program content, direction and effectiveness. The advisory group consisted of representatives from the California Energy Commission; Western United Resource Development, Inc.; U.S. Environmental Protection Agency's AgSTAR Program; California Department of Food and Agriculture; California State Water Resources Control Board; Sustainable Conservation; University of California; and Milk Producers Council. In addition, WURD subcontracted with technical experts to conduct due diligence reviews on the legal, technical, and economic aspects of the proposed projects, and to perform testing and environmental assessment of completed projects.

The program was designed to provide two types of assistance for qualifying dairy biogas projects: buydown grants that cover a percentage of the capital costs of the proposed biogas system, or incentive payments for generated electricity. In general, buydown grants covered a maximum of up to fifty percent of documented capital costs of the biogas system based on estimated power production, but not to exceed $2,000 per installed kilowatt, whichever is less. Electricity generation incentive payments were based on 5.7 cents per kilowatt-hour of electricity generated by the dairy biogas system paid out over a maximum of five years. The total cumulative payments under the incentive payment program were intended (after five years) to equal the amount of funding that would be provided for an equivalently sized digester-to-electricity system under the grant buydown approach.

As mentioned, WURD was responsible for the day-to-day administrative operations of the DPPP. WURD worked with CEC to develop program guidelines and a comprehensive application packet, and acted as liaison among applicants, CEC, and the advisory group. WURD maintained databases for tracking applications, interested parties, and budget and grant accounting, including the tracking and approval of dairy project costs and reimbursements for funded projects, as well as all program expenditures. WURD assisted dairymen and interested parties in understanding program guidelines and application requirements, and coordinated advisory group and due diligence review of applications. WURD maintained all grant agreement and project files and documentation, handled all grant-related correspondence, and performed all administrative reporting and documentation required by CEC. WURD also managed all subcontractor work required for the program.

Program Marketing

With the introduction of the program, WURD conducted an extensive marketing effort throughout the state of California to promote methane digester technology and the grant program. Marketing efforts included direct mailings to all dairy producers, advertisements in major trade publications, press releases, and the development of a website. Advertisements ran in the following trade publications, with a combined circulation of 87,668: *Ag Alert, California Farmer, Capital Press, Dairy Business, Hoard's Dairyman,* and *AgriBusiness*. A total of 532,840 impressions of the advertisement were printed and circulated throughout the duration of the advertising campaign, which ran from August through December 2001.



A database of interested parties, media contacts and vendors was assembled by WURD. Contacts were kept up to date about developments in the program, and the website is updated as necessary. A total of 21 press releases have been issued to date, which have generated media inquiries and coverage on the DPPP in local newspapers, trade publications and radio news programs.

WURD staff members and advisory group members have also promoted the program through presentations at various meetings throughout the state, as well as through meetings and telephone calls with individuals interested in the program.

Flex your POWER[SM]

WURD's website, www.wurdco.com, features general information on the DPPP, as well as up to date and ongoing news clippings related to methane digesters. The website also contains a list of digester developers and vendors who had expressed an interest in working with California dairies on developing methane digester systems. Links to partner agencies and information resources are also highlighted. During the application period, program guidelines and the application packet were available from the website. Finally, detailed information and photographs of completed systems are highlighted on the website.

To date, several well-attended grand opening events have been held for the following completed projects: Castelanelli Dairy, Hilarides Dairy, Cottonwood Dairy, Meadowbrook Dairy, Blakes Landing Farms, and Van Ommering Dairy. Media, as well as local, state, and federal elected officials were invited to these events, in addition to representatives from various regulatory agencies. At these events, stakeholders gave brief overviews of topics including the DPPP, interconnection and net metering, and methane digester technology. Attendees were then taken on a tour of dairies and their digester systems, as dairy owners and project developers described system operation.

Application Submission and Review

A total of 55 applications from dairies located throughout the state of California were received and screened. These applications were submitted to the advisory group for preliminary technical and economic review. Applications deemed suitable by the core advisory group were submitted for legal, technical and financial due diligence review. Two different types of reviews were conducted depending on the type of funding request. Buydown grant applications underwent more rigorous due diligence review than incentive grant applications, as buydown grants were paid out as the projects were constructed, whereas incentive grants were paid only after project were complete and generating electricity. Specific review criteria for the two funding pathways are described below.

Buydown Grant Applications

- Overall suitability of the proposed dairy to employ biogas-to-electricity technology
- Technical assessment of the proposed biogas system to be used at the dairy
- Analysis of the economic feasibility of the proposed project
- Financial feasibility of the proffered project
- Adequacy of applicant’s insurance and indemnification of WURD and the State of California
- Commitment to secure optional performance bond to extend five years from grant date
- Use of service agreements to cover maintenance and/or problems with all equipment related to the digester, including the biogas reactor system, the prime mover, the gas handling and transmission system, and interconnection/switchgear equipment
- Ability of proposed system to comply with existing laws
- Other matters as deemed appropriate to ensure integrity of program funding

Electricity Generation Incentive Payment Applications

- Overall suitability of the proposed dairy to employ biogas-to-electricity technology
- Financial feasibility of the proffered project
- Adequacy of applicant’s insurance and indemnification of WURD and the State of California
- Commitment to secure optional performance bond to extend five years from grant date
- Use of service agreements to cover maintenance and/or problems with all equipment related to the digester, including the biogas reactor system, the prime mover, the gas handling and transmission system, and interconnection/switchgear equipment

- Ability of proposed system to comply with existing laws
- Other matters as deemed appropriate to ensure integrity of program funding

As noted earlier, incentive payment applications were subject to less strenuous technical review, as incentive payment grants were to be paid based on actual production of electricity. Consequently, incentive payment grant applicants took on greater technical and financial risk with this option. The advisory group considered the technical, legal and financial due diligence reports when making final funding determinations.

A number of applications were reviewed but not approved for funding by the advisory group based on the review criteria outlined above. Some applicants withdrew from the program prior to complete review of their applications, for reasons including the following:

- High level of financial obligation required for project, combined with low milk prices
- Lack of interest
- Did not disclose reason
- Technology did not qualify for buydown grant; incentive grant offered but declined by applicant
- Did not agree to terms of grant program
- Proposed projects were for unproven or research and development technology; these applications were forwarded to CEC for consideration under the PIER program
- Permitting issues
- The project completion timeline was not feasible, as new dairy construction would not be completed in time to meet program deadlines
- The project would require more time and involvement than initially expected
- Funding declined by the advisory group upon review

A total of fourteen projects were approved for grant funding, as discussed in the next section.

Program Funding

SB5X made $10 million available for the program. The California Energy Commission allocated $360,000 from the program for state administrative costs, leaving the total program funds at $9,640,000. Of those program funds, $1,030,250 was allocated to WURD for program administrative costs, which includes program marketing, processing of applications, technical and due diligence reviews, project monitoring, testing, and evaluation, and reporting. The remaining $8,609,750 was allocated for project grant awards.

Administrative Funds

The total administrative funds allocated to WURD amounted to $1,030,250. As detailed under the *Program Structure* section of this report, WURD was responsible for all aspects of program implementation, including program marketing, processing and review of applications, project monitoring, testing, and evaluation, processing grant claim reimbursements, as well as monthly, quarterly, and final reporting.

Project Funds

Project funding was budgeted at $8,609,750 for grants. A total of $5,792,370 was encumbered for the fourteen projects recommended for funding by the advisory group. Unencumbered monies totaling $2,817,380 were released back to the state in March 2005. Of the fourteen approved for grant funding, ten projects are complete. The remaining four projects opted not to construct their digester systems due to various fiscal concerns.

Eight of the ten completed projects were funded under the buydown grant option. These projects represent $2,409,770 in total grant awards. All eight buydown grants have been paid in full. Two of the ten completed projects selected the incentive payment method. The two projects represent $964,100 in total grant monies. A balance of $938,241 is still pending to be paid out to the two incentive payment grants as they generate electricity.

Grant award amounts and payment methods for the ten projects are outlined in Table 1 below.

Table 1. Awarded Grants, Purpose of Grant and Type of Grant

Dairy ID	Name	Purpose of Grant	Grant Amount	Grant Type
202	Hilarides Dairy	New covered lagoon digester	$500,000	Buydown
204	Cottonwood Dairy	New covered lagoon digester	$600,000	Buydown
207	Blakes Landing	Refurbishment of existing non-operational covered lagoon digester	$67,900	Buydown
221	Castelanelli Bros.	New covered lagoon digester	$320,000	Buydown
225	Koetsier Dairy	Refurbishment of existing non-operational plug flow digester	$190,925	Incentive
226	Van Ommering Dairy	New plug flow digester	$244,642	Buydown
230	Meadowbrook Dairy	New plug flow digester	$262,449	Buydown
238	Lourenco Dairy	Refurbishment of existing non-operational covered lagoon digester	$114,779	Buydown
248	Inland Empire Utilities Agency	Modification and expansion of operational modified mix plug flow digester	$773,175	Incentive
249	Eden-Vale Dairy	New plug flow digester	$300,000	Buydown

2. Anaerobic Digestion Technologies and Electricity Conversion

Covered Lagoon Digester

A covered lagoon is an earthen lagoon fitted with an impermeable cover that collects biogas as it is produced from flushed manure. The cover is constructed of an industrial fabric that either rests on solid floats laid on the surface of the lagoon or is anchored to the banks. A cover can be placed over the entire lagoon or over only a part. An anaerobic lagoon is best suited for organic wastes with a total solids concentration of 0.5 to 3 percent. Climate is a key factor in the performance of covered lagoons as they are not heated.

Figure 1. Covered Lagoon Digester System

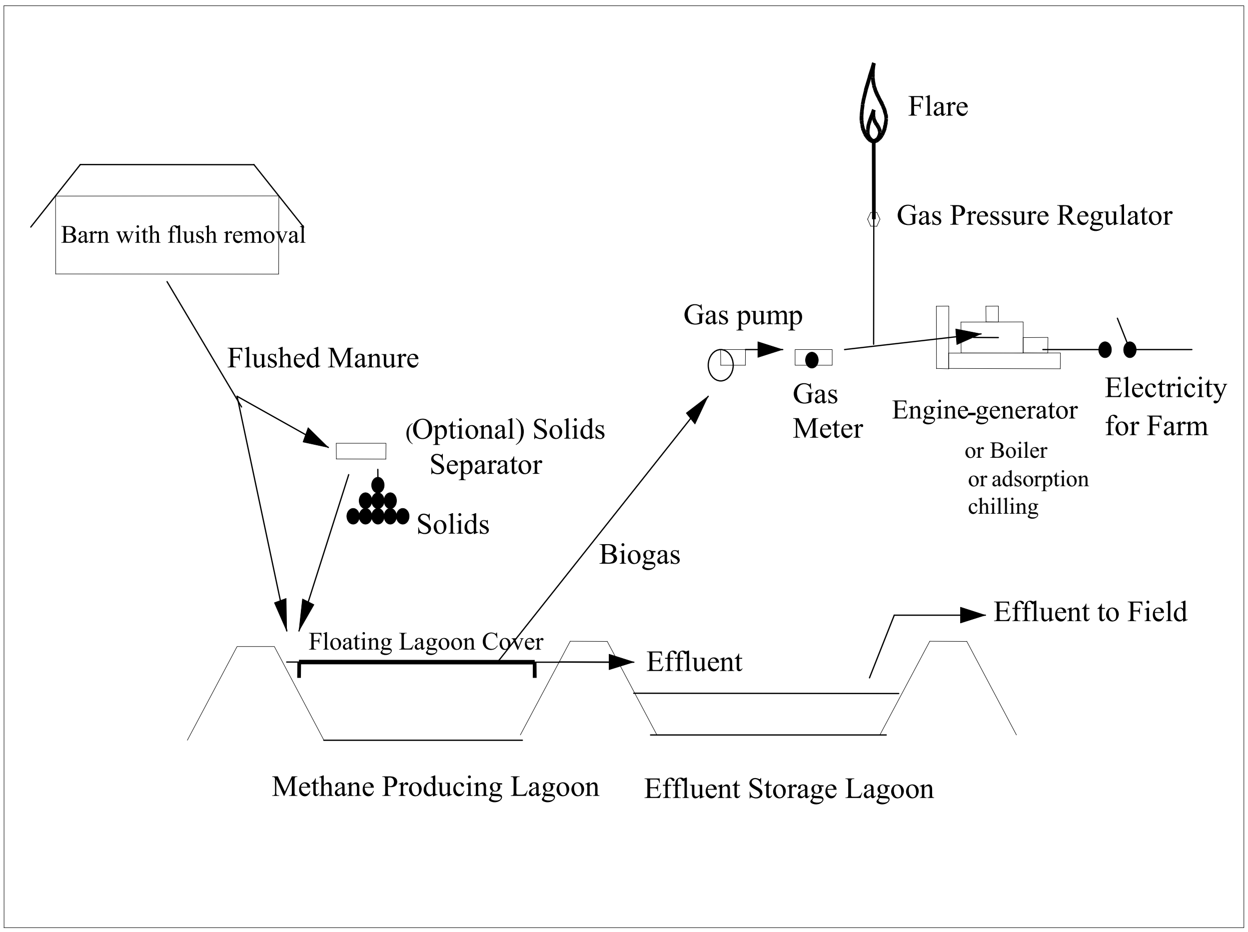


Diagram courtesy of RCM Digesters

Plug Flow Digester

The plug flow digester design is a long linear reactor wherein wastes move slowly through the reactor as a "plug." Plug flow digesters are often built below ground level, with an airtight expandable cover. Manure is collected daily and added to one end of the trough. Each day a new "plug" of organic wastes is added, slowly pushing the other manure down the trough. Plug flow digesters are usually operated with a total solids concentration of 11 to13 percent, at the mesophilic temperature range, and with a hydraulic residence time (HRT) from 20-30 days. Plug flow digesters are usually heated to maintain optimal temperatures.

Figure 2. Plug Flow Digester System

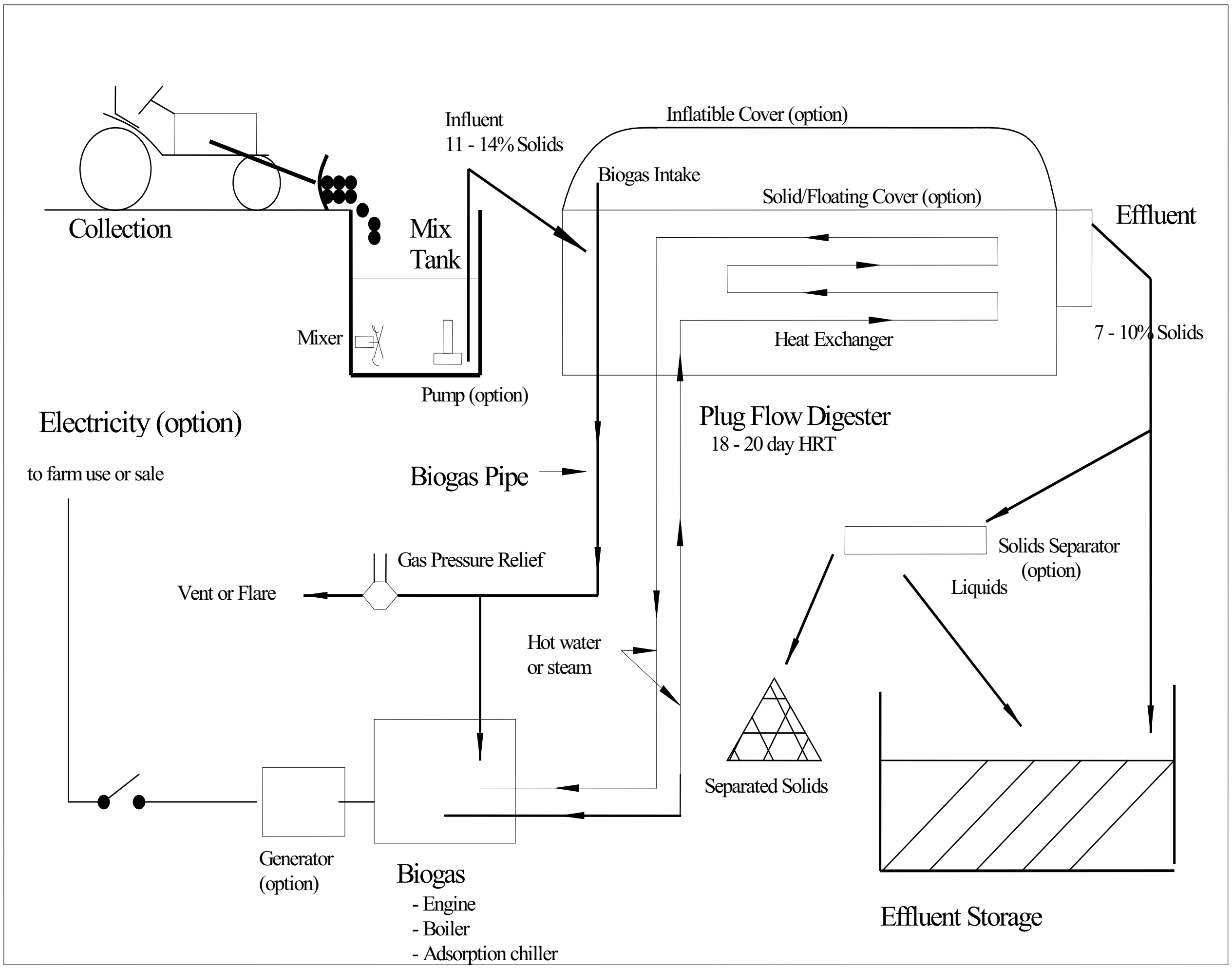


Diagram courtesy of RCM Digesters

Complete-Mix Digester

Complete mix digesters are engineered tanks located above or below ground. They are compatible with a combination of scraped and flushed manure with solids concentration ranging from 3 to 10 percent. A mix tank is used as a control point to reach optimum solids content prior to introduction into the complete-mix digester. A complete-mix digester is held at a controlled temperature and constant volume.

Figure 3. Complete Mix Digester System

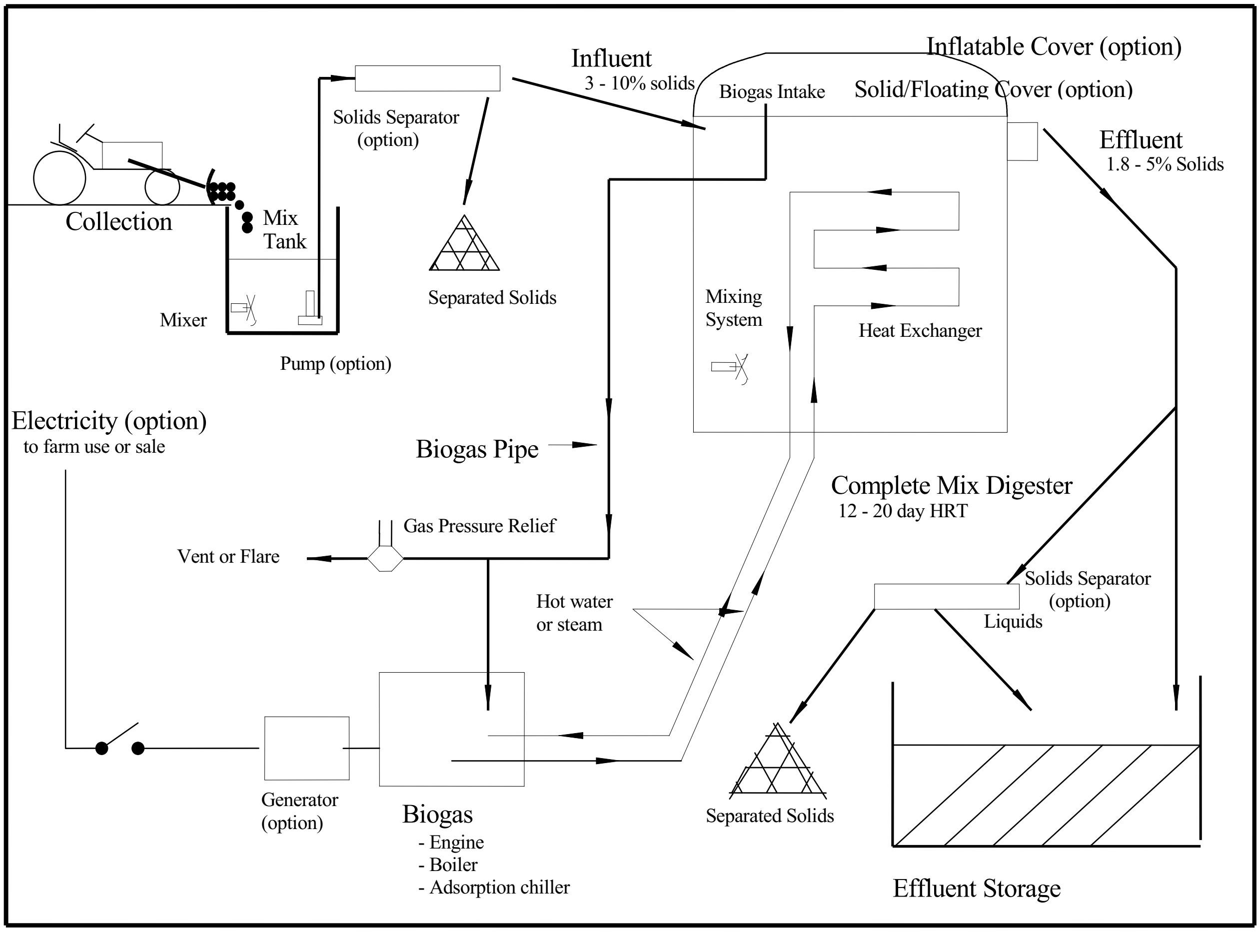


Diagram courtesy of RCM Digesters

Energy Conversion

Biogas produced in an anaerobic digester can be converted to electricity through either an internal combustion (IC) engine connected to an electrical generator, or through a turbine connected to an electrical generator. All of the projects in this program use IC engines. There are a number of technologies available to remove some impurities in the biogas in order to lengthen engine life, reduce engine emissions, or to protect emission control systems on the engines. Two of the grant recipients have installed an iron sponge to remove hydrogen sulfide from the biogas.

3. Utility Issues and Net Metering Background and Overview

Because biogas to electricity systems are only recently being constructed on a more widespread scale on California dairies (largely due to the funding provided through DPPP), utility interconnection and net metering provisions were in their infancy during this program. Utilities had to rework their billing structures to implement interconnection and net metering provisions, while dairy owners worked to understand the complexities of generating electricity in parallel with the grid and the best way to maximize their savings due to the on farm generation of power.

On Site Usage of Generated Power

The largest savings from the generation of power are in the offset of on farm energy needs. Because power purchase agreements are not currently available, the greatest savings are realized when the engine-generator is connected to the main load at the dairy (e.g., the milking parlor, irrigation pumps, etc.). Under this scenario, as electricity is produced, the electricity usage for the dairy is offset (i.e. the amount of electricity imported from the grid is reduced). This reduces the total power purchased from the utility and is valued at the energy rate portion of the full retail rate as specified in their applicable rate schedule. In simple terms, the energy rate is charged per kilowatt-hour (kWh) consumed and varies by season and time of day. It does not include the basic customer charge or demand charge. Unfortunately, for most of the projects involved, the offset of power cannot be valued at the full retail rate (rate which includes all components such as customer charges, energy charges, demand charges, etc.) due to the fact that demand charges are not subsequently reduced. In simple terms, the demand charge is a per-kW charge applied to the greatest amount of demand created in the time period and/or season as specified in the applicable rate schedule. This issue is discussed further below.

Additional savings can be achieved through the net metering of any excess generated power that is not used on farm. Savings associated with net metering come from any accrued net generation credits that can be used against unbilled generation charges on the dairy accounts. Generation credits and generation charges are tracked for twelve month periods. For any time-of-use in which the electrical production exceeds the usage, a generation credit is accrued and valued at the applicable generation rate component. Reconciliation of generation credits and charges takes place at the end of the twelve month period and any unused credits are zeroed out. This process, provided by the utility, is explained further below.

Demand Charges

In most cases, demand charges are a significant portion of the overall monthly utility bill. In reviewing utility bills for several of the projects that use their generated power on farm, it was determined that demand charges comprised approximately 16%-35% of the total utility bill prior to the generation and utilization of on farm power (i.e. prior to the installation of the digester system). Demand charges for these same projects now comprise 35%-59% of the total utility bill. This points out the fact that the use of on farm power has successfully reduced the energy charge portion of the utility bill but demand charges have not subsequently been reduced even though a majority of the on farm electrical needs are now provided by the farm's generated power.

Each project has multiple meters associated with the facility and, in most cases each meter is on a different rate schedule. In reviewing the utility bills for the main or "parent" account, it is apparent that most of the projects are on rate schedules that specify that maximum demand be established by the measured maximum kilowatt input recorded during any 15-minute metered interval. So, at any point when the digester system is down (e.g., due to maintenance or repair), that period of highest recorded demand will be used to establish demand charges for the month. Given this, it is likely that the dairy owner will not be successful in reducing demand charges each month as the system will require some down time. In most cases, this has substantially reduced the potential savings of on farm use of generated power. Even projects with more than one engine-generator have not been able to successfully reduce demand charges due to the great deal of oversight needed to ensure that the performance and operational timing of the generators are such that they are not all down at the same time.

Power Purchase Agreements

None of the utility companies with completed digester projects currently offer power purchase agreements for the power produced by each dairy facility. However, Pacific Gas & Electric has recently expressed interest in implementing a power purchase agreement program. WURD representatives and other interested parties are currently discussing and exploring the opportunity. It is hopeful that some agreement will be reached in the near future. The implementation of power purchase agreements at competitive rates (above the rate they currently enjoy for offset power) could greatly improve the financial feasibility for these projects.

Net Metering

Net metering laws allow electricity generated by a customer to be credited against electricity consumed. Although advantageous, the legislation, AB 2228 (Negrete McLeod), was not passed until 2003. After the law's passage, issues with the utility's interpretation of tariffs had to be worked out with the Public Utilities Commission. It should be noted that AB 2228 sunset on January 1, 2006; however, new legislation, AB 728 (Negrete McLeod), was recently signed by the Governor. This new bill extends and expands the biogas net metering program through December 2009.

Net generation credits are accrued for any time of use during which electrical generation exceeds electrical usage. Net generation credits are valued at the generation rate component of the full retail rate. For the 10 completed projects, the generation rate averaged $0.03 to $0.05 per kilowatt-hour depending on their applicable rate schedule and utility company. One project, whose net generation occurred primarily in the peak time of use period, enjoyed a generation rate of $0.10 per kilowatt hour. However, it should be noted that this system was run only 11 hours per day and operation was targeted towards peak periods. The remainder of the projects targeted an operation of 24 hours per day.

Pacific Gas & Electric (PG&E)

Pacific Gas and Electric Company (PG&E) offers the Net Energy Metering Service for Biogas Customer-Generators (NEMBIO) rate schedule as an option for customers with an eligible biogas digester operating in parallel with PG&E.

NEMBIO works in conjunction with a second, time-of-use rate (TOU) schedule, referred to as the otherwise applicable rate schedule (OAS). The OAS is the basis for not only the charges, but also the generation credits for any electricity exported to the grid. The credits for export are based only on the generation rate component of the rate schedule. All other charges, including but not limited to, transmission charges, distribution charges, monthly customer charges, minimum charges, demand charges, and non-energy related charges are not included when calculating the generation credit for exported electricity.

PG&E aggregates the load (usage) of all eligible metered Time-of-Use (TOU) accounts associated with the dairy operations designated on the interconnection agreement to determine NEMBIO credits and/or charges annually. All of the aggregated accounts serving the dairy operation must be located on property adjacent, or contiguous, to the dairy facility. The main dairy account used for net metering purposes is referred to as the "primary" account by PG&E.

The dairy owner is billed monthly for all charges other than the generation rate component charges on all eligible accounts on the dairy. Then, at the end of each relevant period (twelve monthly billing cycles commencing on the anniversary date of final interconnection) PG&E will complete an annual reconciliation of generation credits and unbilled generation rate components. At the end of the 12-month period, these credits and charges will be zeroed out. The utility is not required to pay for the unused portion of the generation credit.

PG&E does not currently offer power purchase agreements for the excess power produced by each dairy facility.

Southern California Edison (SCE)

Southern California Edison (SCE) offers the Biogas Net Energy Metering Service for Customer-Generators (BG-NEM) rate schedule as an option for customers with an eligible biogas digester operating in parallel with SCE.

Under the SCE net metering program, an electric meter is used to measure and track the "net" difference between the amount of electricity produced and the amount of electricity consumed during each billing period. This is done on a time-of-use basis according to the customer's rate schedule. Twelve monthly billing cycles commencing on the anniversary date of final interconnection is considered the "relevant period."

At the end of each billing period, a credit is given for any energy generated that is in excess of the energy consumed (net generation). Only the generation rate component of the total retail rate is used in the calculation of generation credits. All other charges, including but not limited to, transmission charges, distribution charges, public goods charges, nuclear decommissioning charges, monthly basic service fees, minimum charges, demand charges, and non-energy related charges are calculated prior to the netting of energy supplied or produced, for all energy supplied to the dairy. If energy consumption is greater than the energy produced, the customer is billed the difference. SCE offers the customer an opportunity to "bank" charges for electricity produced in excess of consumption in the form of a credit. This credit can be applied to future generation-related charges on other accounts included in net metering. However, any credits remaining at the end of the 12-month billing period are not paid out by the utility, and are forfeited by the customer-generator. Likewise, any unbilled generation charges that cannot be offset by accrued generation credits must be paid to the utility company.

The main dairy meter used for net metering purposes is referenced by SCE as the "parent" account. The other accounts associated with net metering are referred to as "child" accounts.

SCE does not currently offer power purchase agreements for the excess power produced by each dairy facility.

San Diego Gas & Electric (SDG&E)

San Diego Gas & Electric (SDG&E) offers the Net Energy Metering Service for Biogas Customer-Generators (NEM-BIO) rate schedule as an option for customers with an eligible biogas digester operating in parallel with SDG&E.

An electric meter to measure and track the amount of electricity produced and the amount of electricity consumed during each billing period. This is done on a time-of-use basis according to the customer's rate schedule. Twelve monthly billing cycles commencing on the anniversary date of final interconnection is considered the "relevant period."

At the end of each monthly billing period, a credit is given for energy generated at the dairy. Only the generation rate component of the total retail rate (less generation surcharges) is used in the calculation of generation credits. All other charges, including but not limited to, transmission charges, distribution charges, public goods charges, nuclear decommissioning charges, monthly basic service fees, minimum charges, demand charges, and non-energy related charges are calculated prior to the netting of energy supplied or produced, for all energy supplied to the dairy.

Generation credits are applied towards the generation component of the total utility bill due each month. SDG&E offers the customer an opportunity to "bank" monthly credits. This credit can be applied to future generation related charges. However, any available generation credit dollars in excess of generation charge dollars remaining at the end of the 12-month or "relevant" period are not paid out by the utility, and are forfeited by the customer.

SDG&E does not currently offer power purchase agreements for the excess power produced by each dairy facility.

4. Overview of Installed Projects

Project Locations and Installation

To the extent possible, the advisory team tried to ensure the funded projects span the range of California dairy sizes, geographic locations within the state, and types of dairy manure management practices. The completed projects represent a diverse geographic area spanning from San Diego County to Marin County. The projects are also representative of the distribution of dairies in the state. The locations of the ten completed projects are listed in the table below.

Table 2. Distribution of Completed Projects

Dairy ID	Name	Location	County
202	Hilarides Dairy	Lindsay, CA	Tulare
204	Cottonwood Dairy	Atwater, CA	Merced
207	Blakes Landing Farms	Marshall, CA	Marin
221	Castelanelli Bros.	Lodi, CA	San Joaquin
225	Koetsier Dairy	Visalia, CA	Tulare
226	Van Ommering Dairy	Lakeside, CA	San Diego
230	Meadowbrook Dairy	El Mirage, CA	San Bernardino
238	Lourenco Dairy	Tulare, CA	Tulare
248	Inland Empire Utilities Agency (IEUA)	Chino, CA	San Bernardino
249	Eden-Vale Dairy	Lemoore, CA	Kings

The completed projects also reflect the three types of digester systems previously discussed: covered lagoon, plug flow and modified mixed plug flow digesters. The completed projects also represent a range of cow numbers and generating capacity. The table below lists the characteristics of the ten completed projects.

Table 3. Characteristics of Completed Projects

Dairy ID	Name	Digester Type	Generating Capacity (kW)
202	Hilarides Dairy	Covered Lagoon	500
204	Cottonwood Dairy	Covered Lagoon	300
207	Blakes Landing Farms	Covered Lagoon	75
221	Castelanelli Bros.	Covered Lagoon	160
225	Koetsier Dairy	Plug Flow	260
226	Van Ommering Dairy	Plug Flow	130
230	Meadowbrook Dairy	Plug Flow	160
238	Lourenco Dairy	Covered Lagoon	150
248	Inland Empire Utilities Agency (IEUA) – Phase 1B	Modified Mix Plug Flow	563
249	Eden-Vale Dairy	Plug Flow	180

Major Obstacles to Project Completion

Each project was completed much later than originally anticipated in the grant application submitted to WURD. Project completion ranged from 3 to 4 years from the date of grant application with most projects completed in 2004 and 2005. A full discussion of the major obstacles is included in the individual case studies to follow. However, a few reoccurring roadblocks should be mentioned.

- **Historically low milk prices**: Low milk prices had significant impact on participants in the grant program. Beginning in late 2001 (around the time most grant applications were submitted), low milk prices began to put a strain on a dairy farmer's ability to obtain funds to invest in methane digester projects. Prices received by dairy farmers were at the lowest levels witnessed in over 25 years. Though dairy markets are typically cyclical in nature, producers experienced more than 20 months of extremely low prices. These low prices were, in most months, below a dairy producer's cost of producing milk. This put a huge damper on any interest in investing in the large capital outlay needed to build a digester system, even with grant monies available.

- **Permitting issues**: Several of the projects experienced significant delays in obtaining their necessary permits in order to begin construction. One project reported a two and a half year delay in obtaining the necessary county permits. By the time permits were obtained, the cost of construction materials had escalated, adding hundreds of thousands of dollars to project expenses.

- **Interconnection delays:** For several of the projects, working out the interconnection and net metering arrangements with their local utility took longer than initially expected, and delayed, beyond the dairy owner's control, the completion of the project. Dairy owners reported the utility interconnection agreement continued to prove elusive, with requirements changing several times. Further, for some of the projects, billing from the utility company was delayed for several months as these projects were the first biogas net metering customers in the state and the utilities had to work out net metering billing procedures.

- **Net metering legislation**: It was a cumbersome and time consuming process of getting net metering legislation passed in order to allow net electricity generated by a utility customer to be credited against electricity consumed. Although advantageous, this legislation, AB 2228 (Negrete McLeod), was not passed until 2003. After the law's passage, issues with the utility's interpretation of tariffs had to be worked out with the Public Utilities Commission. It should be noted that AB 2228 sunset on January 1, 2006; however, new legislation, AB 728 (Negrete McLeod), was signed by the Governor. This new bill extends and expands the biogas net metering program through December 2009.

- **Weather related delays**: The extremely wet winter of 2005 delayed several of the projects close to completion.

5. Case Studies: Covered Lagoon Digesters

Project #207: Blakes Landing Farms

Project #207	Blakes Landing Farms
Contact	Albert Straus
City, County	Marshall, Marin County
General System Information	
Operational date:	June 2004; Net metering began July 2004
Reporting period:	July 2004 – June 2005
Herd size:	245 lactating; 28 dry; 89 heifers; 82 calves; 3 bulls
System type:	Covered lagoon (system refurbishment)
Dimensions:	150 × 60 × 12 ft. deep
Project history:	• Application submitted December 14, 2001 • Approved for funding April 2002 • Operational June 2004
Designer/Installer:	Williams Engineering Associates
Generator nameplate capacity:	75 kW
Engine make/model:	Waukesha 817G
System Costs	
Estimated costs:	$135,800 for refurbishment
Actual costs:	$159,680 for refurbishment $175,000 in initial costs to convert lagoon to anaerobic digester (includes installation of cover)
Operation & maintenance:	$329 per month average
DPPP funding:	$67,900 to refurbish existing digester system (buydown)
Other funding:	U.S. EPA through the California Regional Water Quality Board: $87,361
Unexpected costs:	$7,605 for a heating system; $11,500 for expansion of hot water distribution system (included in actual costs above)
Manure Collection and Handling	
Manure collection:	Flush
Digester feeding mode:	Intermittent
Digester inflow:	30,000 gallons per day including 10,000 of creamery wastewater
Retention time:	34 days

Project #207 (continued)	Blakes Landing Farms
System Performance	
Biogas Production:	
Average per month (cubic feet)	451,922
Average per day (cubic feet)	14,832
Per cow (cubic feet per day)	61
Estimated biogas flared	None reported
Electrical Production:	
Generator nameplate capacity (kW)	75
Generator operation (average hours/day) and actual generation (% of capacity)	11.9 hours/day; 38%
Average per month (kWh)	21,066
Average per day (kWh)	692
Total per cow (kWh/day/cow)	2.82
Energy Usage and Utility Information	
Utility Company:	Pacific Gas & Electric (PG&E)
Average Energy Usage: [1]	
Prior to installation (kWh per month)	20,375 per month average on primary dairy account; 21,597 on all dairy accounts; 84,813 per month on creamery account
Study period (kWh per month)	11,560 per month average on primary dairy account; 12,652 on all dairy accounts; 96,680 on creamery account
Net metering?	Yes - 4 dairy meters and creamery meter included Avg. net generation on primary: 8,807 kWh per month Avg. net consumption on primary: 11,560 kWh per month
Use of generated power:	Offset on farm usage; some net metering; no power purchase agreement

[1] Any changes year-to-year would not only capture offset due to generated energy used on farm but also any changes in the daily operations such as cow numbers, weather related energy usage fluctuations, etc.

Project #207 (continued)	Blakes Landing Farms
Estimated Savings	
From on-farm offset:	• $18,275 per year or $1,523 per month avg. • Savings est. at rate of $0.12/kWh (Primary account is on AG4A rate which keeps demand charges small and constant year-to-year)
From net generation:	• $897 per year or $75 per month avg. • Savings est. at generation rate of $0.10/kWh (most net generation is during peak or partial peak periods)
Thermal savings from recovered heat?	Yes, estimated savings of $300 per month due to offset of propane usage from use of recovered heat. It is estimated that approximately 48% of propane usage was offset. During study period, propane costs averaged $1.67 per gallon. Currently, the dairy owner is paying $2.15 per gallon. At these rates, total monthly savings will approach $400 per month.
Other benefits:	None reported
Estimated Simple Payback Period (based on final costs for refurbishment):[2]	With no grant funding: 8.7 years After DPPP funding: 5.0 years After all grant funding: 0.2 years
Estimated Simple Payback Period (based on initial costs for existing and final costs for refurbishment):	With no grant funding: 18.3 years After DPPP funding: 14.6 years After all grant funding: 9.8 years
Obstacles, Dairy Owner Feedback and Suggestions	
Major obstacles faced:	• Low milk prices late 2001-mid 2003 • Obtaining Rule 21 interconnection permit • Net metering legislation
Dairy owner feedback: Ranked 1-4, with 1=poor and 4=excellent	Ease in operating systems: 2.83 Advantages gained for manure mgt: 3.67 Odor control benefits: 4.00 Reduction in water usage: 3.75 Addresses electrical issues: 3.17 Overall satisfaction: 3.00
Suggestions for improvements and/or lessons learned:	• The purchase of a new engine-generator. Costs may have been offset by PG&E and would have resulted in a newer/more efficient unit. • Lack of power purchase agreements for generated power reduced economic feasibility

[2] Simple payback does not consider the time value of money, inflation, or operation and maintenance costs

Project #207 (continued)	Blakes Landing Farms
Recent Developments	
Additional costs incurred (not included in actual costs above):	• Added a computerized Beckwith controller to control engine output at $1,800 cost • Computer to monitor generator electricity output at $1,300 cost • Engine head rebuild at $2,000 cost
Significant changes implemented:	• Increased herd size by about 20 cows. Currently averaging 270 lactating and 30 dry • Has added 4 employee houses to net metering
Significant changes planned:	• Looking to improve the design (a more modern engine that is quieter and more efficient) or alternative generation systems such as fuel cell or turbines. • Looking at rewiring to connect more dairy load to the main meter to have his generation offset the full load on the other meters. • Would like to utilize more recovered heat for heating the digester. Heat exchanger in the pond is currently disconnected.
Recent operational problems:	Some leaks in the cover and some work needs to be done where the covers are anchored to the sides of the digester. When the biogas is pulled to the generator, air is leaking into the flow, thus reducing kW production. Expects to have it fixed soon. They've also had to do some work to the engine (rebuild the head due to regular wear and tear at a cost of about $2,000).

General System Overview

The cows are housed primarily in freestall barns and pasture. The number of cows housed in the freestall barns fluctuates greatly by season. For instance, in mild weather, the cows are housed primarily on pasture and brought in only for milking. This fluctuation in the number of cows housed in the freestall barns, where the manure is collected, greatly impacts the performance of the digester system. In the winter, all of the milk cows and dry cows are housed indoors, as well as about 30 of the heifers. Additionally, about 125 of the calves, age 8 months and younger, are indoors. From March through October, 160 milk cows are on pasture for part of the day. From March through June, they are housed indoors for 13 hours a day. From June through October, they are housed for 18 hours a day.

In addition to the working dairy, there is also a small creamery that is owned and operated by the dairy owner. The creamery produces fluid milk, cream, eggnog, yogurt and butter products.

Approximately 20,000 gallons of manure and flushed water enter the lagoon on a daily basis. In addition to the 20,000 gallons of manure/flushed water from the dairy farm, approximately 10,000 gallons of creamery wastewater were added per day. These numbers fluctuate given the time of the year and the number of cows on pasture versus in the freestall barns.

A screw press separator is used to separate the solids before entering the 9,000 square foot lagoon. The solids are composted and land-applied as fertilizer. The screened manure is intermittently charged to the covered-lagoon digester measuring 150 feet in length, 60 feet wide, and 12 feet deep with a total volume of 72,000 cubic feet with a hydraulic retention time of 34 days. The produced biogas is passed through condensate and sediment traps and used to power a 75-kW (100 hp)-capacity Waukesha engine-generator set. Digester effluent is treated in four storage lagoons in series. Part of the lagoon water is recycled for flushing manure.

As anticipated, the generator runs approximately 11 hours per day. When the generator is not in operation, the biogas is not flared, but rather, is collected and stored in the covered lagoon. Additionally, a heat exchange plate that uses reclaimed heat from the engine was installed in the pond, raising the lagoon temperature from approximately 75 degrees to 85 degrees Fahrenheit. This increase in temperature resulted in increased biogas production. The heat exchange plate is expected to maintain a year-round psychrophilic temperature range of approximately 75 to 85 degrees Fahrenheit, depending on seasonal outside temperature.

Project #221: Castelanelli Bros.

Project #221	Castelanelli Bros.
Contact	Larry Castelanelli
City, County	Lodi, San Joaquin County
General System Information	
Operational date:	October 2004
Reporting period:	October 2004 – September 2005
Herd size:	1601 lactating; 205 dry; 1,408 heifers; 367 calves; 20 bulls
System type:	Covered lagoon (new system)
Dimensions:	550 × 150 × 28 ft. deep
Project history:	• Application submitted December 2001 • Approved for funding April 2002 • Operational October 2004
Designer/Installer:	RCM Digesters
Generator nameplate capacity:	160 kW
Engine make/model:	Caterpillar 3406T
System Costs	
Estimated costs:	$772,925
Actual costs:	$882,136
Operation & maintenance:	$950 per month – daily monitoring and oil changes every 350 hours
DPPP funding:	$320,000 (buydown)
Other funding:	• $166,580 USDA/Energy Efficiency & Renewable Energy Program • $60,816 PG&E Self Generation Incentive Program
Unexpected costs:	
Manure Collection and Handling	
Manure collection:	Flush system
Digester feeding mode:	Intermittently (1-6X per day)
Digester inflow:	541,495 gallons per day
Retention time:	40 days

Project #221 (continued)	Castelanelli Bros.
System Performance	
Biogas Production:	
Average per month (cubic feet)	2,708,625 cubic feet (represents both flared and that utilized by engine-generator)
Average per day (cubic feet)	89,148 cubic feet (represents both flared and that utilized by engine-generator)
Per cow (cubic feet per day)	56 cubic feet
Estimated biogas flared	As high as 50%; Beginning April 2006 a flare meter was installed. April-June 2006 an estimated 44% of total biogas production was flared.
Electrical Production:	
Generator nameplate capacity (kW)	160 kW
Generator operation (average hours/day) and actual generation (% of capacity)	20 hours/day; 75%
Average per month (kWh)	87,880 *note: system was down mid-June-mid July 2005*
Average per day (kWh)	3,104
Total per cow (kWh/day/cow)	1.94
Energy Usage and Utility Information	
Utility Company:	Pacific Gas & Electric (PG&E)
Average Energy Usage:	
Prior to installation (kWh per month)	72,313 per month average for all dairy accounts on net metering billing
Study period (kWh per month)	75,899 per month average for all dairy accounts on net metering billing
Net metering?	Yes – 19 dairy meters included Avg. net generation of primary: 84,447 kWh per month Avg. net consumption of primary: 1,520 kWh per month
Use of generated power:	Only net metering; no on-farm usage of generated power during study period; no power purchase agreement. See discussion below for recent developments.

Project #221 (continued)	Castelanelli Bros.
Estimated Savings	
From on-farm offset:	None. However, it should be noted that four dairy accounts were connected to the engine-generator in 2006. Actual savings are unknown, however using historical usage figures estimated savings could average $3,423 per month, bringing total savings (from on-farm usage and net metering) to an estimated $6,151 per month.
From net generation:	• Monthly generation credits averaged $4,371 per month; however only those credits that can be used towards unbilled generation charges are realized savings. Excess generation credits are zeroed out at end of 12-month period. • Realized savings averaged $2,728 per month. • Savings est. at generation rate of $0.033/kWh • On average, $1,643 per month in excess generation credits were forfeited.
Thermal savings from recovered heat?	None reported
Other benefits:	None reported
Estimated Simple Payback Period (based on final costs and estimated savings during study period):[3]	With no grant funding: 26.9 years After DPPP funding: 17.2 years After all grant funding: 10.2 years
Estimated Simple Payback Period (based on final costs and estimated savings due to on farm usage in 2006):	With no grant funding: 12.0 years After DPPP funding: 7.6 years After all grant funding: 4.5 years
Obstacles, Dairy Owner Feedback and Suggestions	
Major obstacles faced:	• Low milk prices late 2001-mid 2003 • Obtaining Rule 21 interconnection permit • Net metering legislation
Dairy owner feedback: Ranked 1-4, with 1=poor and 4=excellent; na=no answer	Ease in operating systems: .... 3.58 Advantages gained for manure mgt: .... 2.86 Odor control benefits: .... 3.92 Reduction in water usage: .... na Addresses electrical issues: .... 1.83 Overall satisfaction: 4.0
Suggestions for improvements and/or lessons learned:	• Better communication with utility • Install larger engine-generator • Engine that turns slower • No turbo on engine • Wire engine-generator direct to dairy facility • Generator was not run at capacity because there was no compensation available for excess generated power. This greatly reduced the financial feasibility of the project. • Power purchase agreements with the utility should be available

[3] Simple payback does not consider the time value of money, inflation, or operation and maintenance costs

Project #221 (continued)	Castelanelli Bros.
Recent Developments	
Additional costs incurred (not included in actual costs above):	Engine rebuild at 6,500 hrs at a cost of about $3,000
Significant changes implemented:	In 2006, the milk barn, 3 lagoon pumps, well and separator were re-wired to the engine-generator at a cost of about $84,727. As noted above, this should enhance the financial feasibility of the project and lower the payback period.
Significant changes planned:	Dairy owner is working to connect as much of the dairy's load to the engine-generator as possible.
Recent operational problems:	Engine rebuild at 6,500 hrs at a cost of about $3,000
General System Overview	

The lactating cows are housed primarily in freestall barns where they spend approximately 21 hours each day. They spend the other three hours in the milking parlor. The dry cows, heifers and bulls spend approximately 12 hours in drylots and 12 hours in feed aprons. The calves are housed full time in a separate barn.

The milking parlor/sprinkler pen, freestall barns and feed aprons are all flushed with either fresh or recycled water two to three times daily. On average, the milking parlor/sprinkler pen is flushed with approximately 77,095 gallons per day of fresh water and 464,400 gallons per day of recycled water for a total of 541,495 gallons per day fed to the digester.

The flushed liquid is moved to a receiving tank and then lifted over an inclined screen separator to remove solids. The separated dry solids are used for bedding in the barns or for soil amendment on the dairy's cropland. The screened liquid is charged to a lagoon digester. The dairy had two existing lagoons. A third lagoon measuring 550 feet long × 150 feet wide × 28 feet deep was constructed for the digester project. This lagoon was topped with a floating cover to convert the lagoon to a digester, and to store the biogas. The cover is made of a high-density polyethylene material measuring approximately 80 mil thick.

The digester is fed intermittently, one to six times per day, and maintained at ambient temperatures. The anaerobic digester has an estimated hydraulic retention time of 40 days. A slow turning propeller within the lagoon helps prevent sedimentation, circulating the lagoon water to help cool the engine and heat the lagoon slightly.

The biogas is used to drive a Caterpillar 3406T engine-generator unit with a 160 kW capacity.

Digester effluent is conveyed to the other existing lagoon where it is stored, mixed with irrigation water and used for land application or as recycled water for flushing.

Project #204: Cottonwood Dairy

Project #204	**Cottonwood Dairy**
Contact	Carl Morris
City, County	Atwater, Merced County
General System Information	
Operational date:	September 2004
Reporting period:	September 2004-August 2005
Herd size:	4,971 lactating; 645 dry
System type:	Covered lagoon (new system)
Dimensions:	1213 × 267 × 24 ft. deep
Project history:	• Application submitted December 2001 • Approved for funding May 2002 • Operational September 2004
Designer/Installer:	Williams Engineering Associates
Generator nameplate capacity:	300 kW for 1st generator operating during study period
Engine make/model:	Caterpillar G3412TS
System Costs	
Estimated costs:	$1,289,520
Actual costs:	$2,498,038
Operation & maintenance:	$ 6,200 per month
DPPP funding:	$600,000 (buydown)
Other funding:	$240,000 PG&E Self Generation Incentive Program
Unexpected costs:	Costs exceeded projections in most areas. See recent additional costs below.
Manure Collection and Handling	
Manure collection:	Flush system
Digester feeding mode:	Continuous
Digester inflow:	1,546,000 gallons per day including 600,000 gallons per day of dilute cheese plant wastewater
Retention time:	34 days

Project #204 (continued)	Cottonwood Dairy
System Performance	
Biogas Production:	
Average per month (cubic feet)	3,433,333 cubic feet utilized by generator
Average per day (cubic feet)	112,957 cubic feet utilized by generator
Per cow (cubic feet per day)	23 cubic feet utilized by generator
Estimated biogas flared	Approximately 50% during study period.
Electrical Production:	
Generator nameplate capacity (kW)	300 kW for study period
Generator operation (average hours/day) and actual generation (% of capacity)	20 hours/day; 81%
Average per month (kWh)	177,757 kWh
Average per day (kWh)	5,850 kWh
Total per cow (kWh/day/cow)	1.18 kWh
Energy Usage and Utility Information	
Utility Company:	Pacific Gas & Electric (PG&E)
Average Energy Usage: [4]	
Prior to installation (kWh per month)	908,200 per month average for cheese plant
Study period (kWh per month)	716,600 per month average for cheese plant
Net metering?	No
Use of generated power:	Offset electrical usage at on farm cheese plant
Estimated Savings	
From on-farm offset:	• \$158,792 per year or \$13,233 per month. Estimated at average energy rate of \$0.0748 per kWh offset. • Demand charges have not been subsequently reduced. Use of on-farm generation cannot be valued at full retail rate. • With 2nd generator electrical generation, cost savings could increase by at least \$10,801 per month reaching a total estimated savings of \$24,034 per month. However, the 2nd generator has not been running at expected levels so these estimates are likely on the low side.
From net generation:	None. Not net metering

[4] Any changes year-to-year would not only capture offset due to generated energy used on farm but also any changes in the daily operations such as cow numbers, weather related energy usage fluctuations, etc. Production in cheese plant was up 20-25% over 2003 levels resulting in greater electrical usage.

Project #204 (continued)	Cottonwood Dairy
***Estimated Savings** (continued)*	
Thermal savings from recovered heat?	• Exhaust heat is used to generate steam for the cheese plant. Some of the engine heat is used to preheat boiler feed water (1st engine), or to preheat air intake to a whey products dryer (2nd engine). • Estimated reduction of about 5,800 gallons of propane per month from the 1st engine-generator alone. At recent propane cost of $1.20 per gallon, this amounts to an estimated savings of about $7,000 per month.
Other benefits:	Just begun to sell some carbon credits. At current rates, this could generate up to an estimated $100,000 per year or $8,333 per month.
Estimated Simple Payback Period (based on final costs and estimated savings during study period):[5]	With no grant funding: 10.3 years After DPPP funding: 7.8 years After all grant funding: 6.8 years
Estimated Simple Payback Period (based on final costs and estimated savings from both generators and potential carbon credit sale):	With no grant funding: 5.3 years After DPPP funding: 4.0 years After all grant funding: 3.5 years
Obstacles, Dairy Owner Feedback and Suggestions	
Major obstacles faced:	• Low milk prices late 2001-mid 2003 • Lengthy permit process for lagoon construction • Lengthy permit process for engine-generator • Interconnection process
Dairy owner feedback: Ranked 1-4, with 1=poor and 4=excellent; na=no answer	Ease in operating systems: 2 Advantages gained for manure mgt: 2 Odor control benefits: 2 Reduction in water usage: 2 Addresses electrical issues: 4 Overall satisfaction: 3
Suggestions for improvements and/or lessons learned:	• Consider all alternatives carefully before moving ahead • Check out all contractors, equipment, and service providers carefully • Make sure economics of project work, and challenge all assumptions • Assume there will be significant cost overruns and time delays • Apply for all permits and electrical interconnects early, and stay on top of these processes • Grants and subsidies are important

[5] Simple payback does not consider the time value of money, inflation, or operation and maintenance costs. Does include estimated savings from offset of propane usage.

Project #204 (continued)	Cottonwood Dairy
Recent Developments	
Additional costs incurred (not included in actual costs above):	• \$500,000 for the purchase and installation of a 2nd engine-generator • Iron sponge media on gas scrubber changed out about every 6-8 weeks, at a cost of \$5,000-\$8,000 each time.
Significant changes implemented:	• The cheese plant complex, where the electricity is used, has continued to expand, with a new building added in 2006. This increased overall electricity demand. A 2nd engine-generator was added in 2006 to utilize more of the biogas produced and generate an additional 400 kW of electricity, for a total of 700 kW. • In June 2006, the 2nd engine-generator utilized 4,044,920 cubic feet of biogas and generated 144,350 kWh of electricity. The engine-generator was not operating at full capacity. • Replaced gas scrubber. The old one was too small and needed a moist environment in order to function. A larger scrubber from a different vendor but similar technology (iron sponge) was installed. It was placed near the digester, before the dryer, so the gas would be moist. A caustic soda spray system was added to keep the environment in the scrubber moist and at the proper high pH level. After some "tweaking" of control systems and operations, the new scrubber works well. However, with the volume of gas flowing through it and the high H2S content in the raw biogas, the iron sponge media has to be changed out about every 6-8 weeks, at a cost of \$5,000-\$8,000 each time. A scrubber with a different technology is expected to be installed when the Columbard dairy digester is complete.
Significant changes planned:	• In the permitting stage for a different technology digester for the Columbard dairy, which is adjacent to the Cottonwood dairy. The plan is to pipe biogas from that digester to the Cottonwood digester area, combine the gas streams, treat them both with a new H2S scrubber, then pipe the treated gas through the existing pipeline to the cheese plant complex, where the extra gas will be used as boiler fuel to replace propane. This project should be completed by late 2007 or early 2008. • The 2nd engine-generator is not fully operational. A larger blower near the digester is needed in order to transfer enough gas to operate both engine-generators at full capacity. Expected to be installed by mid-August 2006.
Recent operational problems:	There were numerous "startup" issues with the project, and again with the 2nd engine-generator, that took some time and expense to resolve. The engine-generators require significant periodic maintenance, and are subject to breakdowns. The H2S scrubber is also expensive to maintain.

Project #204 (continued)	Cottonwood Dairy

General System Overview

The lactating cows are housed primarily in freestall barns and feed aprons where they spend approximately 15 hours each day. They spend approximately 6 hours per day in drylots and the other 3 hours in the milking parlor. The dry cows spend approximately the same time in the freestall barns and feed aprons; but spend 9 hours in drylots.

The milking parlor/sprinkler pen, freestall barns and feed aprons are all flushed daily with either fresh water or recycled cheese plant wastewater. On average, a total of approximately 1,546,000 gallons of water is used per day, including 600,000 gallons of cheese plant wastewater. Approximately 60% of the manure generated on the dairy is collected and sent to the digester. Nutrients in the cheese plant wastewater increase biogas production by an estimated 40%.

A system of concrete trenches collects the waste. Flushed manure slurry is conveyed to a receiving pit. It is then passed through a 50-foot high inclined screen or "separator" to separate manure solids. The separated, dry solids are used for animal bedding or are composted for land application as fertilizer. Dilute, screened manure is piped to a 1200' × 250' × 24' deep covered lagoon digester with an approximate capacity of 44,225,000 gallons. The unmixed, unheated digester receives approximately 1,300,000 gallons per day and has an estimated hydraulic retention time of 34 days. A high-density polyethylene material covers the lagoon, and natural microbial action converts the nutrients in the manure into methane.

Slurry filled pipes are used to hold the cover down and channel the gas to collection pipes located under the cover. Rainwater is channeled on top of the cover and is pumped to an overflow lagoon. The overflow lagoon measures 540' × 1200' × 24' with a capacity of approximately 94,464,000 gallons.

The captured biogas is channeled to a pipeline where it is piped approximately 4,750 feet or 9/10 of a mile to the engine-generator. Produced biogas is used to power a 300-kW-capacity Caterpillar G3412TA engine-generator. Digested manure water flows to a secondary storage lagoon from which it is pumped into the ranch irrigation system for application to crops.

Project #202: Hilarides Dairy

Project #202	Hilarides Dairy
Contact	Rob Hilarides
City, County	Lindsay, Tulare County
General System Information	
Operational date:	September 2005
Reporting period:	September 2005 – July 2006 (11 months)
Herd size:	6,000 heifers
System type:	Covered lagoon (new system)
Dimensions:	Lagoon #1: 1,100 × 220 × 18 ft. deep Lagoon #2: 1,100 × 220 × 15 ft. deep
Project history:	• Application submitted October 2001; revised March 2003 • Approved for funding March 2003 • Operational September 2005
Designer/Installer:	Sharp Energy
Generator nameplate capacity:	(4) 125 kW capacity generators for a total of 500 kW
Engine make/model:	(4) Caterpillar G342 engines
System Costs	
Estimated costs:	$1,500,000
Actual costs:	$1,239,923
Operation & maintenance:	$1,500-$2,000 per month
DPPP funding:	$500,000 (buydown)
Other funding:	None
Unexpected costs:	None reported
Manure Collection and Handling	
Manure collection:	Flush system
Digester feeding mode:	Continuous
Digester inflow:	180,000 gallons per day
Retention time:	67 days

Project #202 (continued)	Hilarides Dairy
System Performance	
Biogas Production:	
Average per month (cubic feet)	7,066,177 cubic feet utilized by generators
Average per day (cubic feet)	232,681 cubic feet utilized by generators
Per cow (cubic feet per day)	39 cubic feet utilized by generators
Estimated biogas flared	20-40%
Electrical Production:	
Generator nameplate capacity (kW)	500 kW for study period (4 each with 125kW capacity)
Generator operation (average hours/day) and actual generation (% of capacity)	22 hours/day; 77% and 82% since all 4 generators have been operating (as of November 2005)
Average per month (kWh)	280,872 kWh
Average per day (kWh)	9,268 kWh
Total per cow (kWh/day/cow)	1.54 kWh
Energy Usage and Utility Information	
Utility Company:	Southern California Edison (SCE)
Average Energy Usage: [6]	
Prior to installation (kWh per month)	133,405 per month average for primary dairy account ("parent") ; 196,805 for all seven dairy accounts
Sep 05-June 06 (kWh per month)	13,645 per month average for primary dairy account ("parent"); 49,919 for all seven dairy accounts
Net metering?	• Yes – 7 dairy meters included in net metering during study period (13 additional meters added Summer 2006 to utilize unused generation credits) • Avg. net generation of "parent": 103,006 • Avg. net consumption of "parent": 13,645
Use of generated power:	Offset on-farm usage; net meter excess electricity

[6] Any changes year-to-year would not only capture offset due to generated energy used on farm but also any changes in the daily operations such as cow numbers, weather related energy usage fluctuations, etc.

Project #202 (continued)	Hilarides Dairy
Estimated Savings	
From on-farm offset:	• $125,709 per year or $10,476 per month. Estimated at average energy rate of $0.06 per kWh offset. • Demand charges have not been subsequently reduced. Use of on-farm generation cannot be valued at full retail rate.
From net generation:	• Monthly generation credits averaged $4,490 per month; however, only those credits that can be used towards unbilled generation charges are realized savings. Excess generation credits are zeroed out at end of the 12-months. • Realized savings averaged $1,734 per month. • Net generation credits valued at an average $0.04/kWh • On average, $2,756 per month in excess generation credits forfeited.
Thermal savings from recovered heat?	Some for hot water
Other benefits:	None reported
Estimated Simple Payback Period (based on final costs and estimated savings during study period):[7]	With no grant funding: 8.5 years After DPPP funding: 5.1 years After all grant funding: 5.1 years
Obstacles, Dairy Owner Feedback and Suggestions	
Major obstacles faced:	• Low milk prices late 2001-mid 2003 • Lengthy permit process for dairy development (3 ½ years and $1 million for EIR) • Net metering legislation
Dairy owner feedback: Ranked 1-4, with 1=poor and 4=excellent; na=no answer	Ease in operating systems: 4 Advantages gained for manure mgt: 4 Odor control benefits: na Reduction in water usage: na Addresses electrical issues: 4 Overall satisfaction: 4
Suggestions for improvements and/or lessons learned:	• Keep the system simple and user friendly • Would have preferred 2 or 3 larger engine-generators rather than the 4 smaller ones

[7] Simple payback does not consider the time value of money, inflation, or operation and maintenance costs.

Project #202 (continued)	Hilarides Dairy
Recent Developments	
Additional costs incurred (not included in actual costs above):	None reported
Significant changes implemented:	Summer 2006: 13 additional dairy meters added to net metering in order to use more of the accumulated generation credits
Significant changes planned:	• Possible increase to 9,000 cows from current 6,000 cows. • Possible purchase/installation of additional engine-generator in 2007.
Recent operational problems:	Only weather related; rain runoff changed the lagoon level more quickly than expected

General System Overview

Manure for the covered lagoon digester is currently collected only from the heifer facility. At this time, manure from the dairy facility is not used in the system. As long as the heifer facility produces enough biogas to generate sufficient energy to supply power needs to the dairy, the owner does not plan on adding the dairy manure to the system. Manure from feed alleys at the heifer ranch is flushed daily using recycled lagoon water, generating 180,000 gallons of flushed manure water daily. This manure water gravity flows into four settling ponds that are cleaned twice yearly to remove manure solids directly to cropland. The manure water is pumped by floating pumps to the north end of covered digester lagoon #1, where most of the gas production occurs. The overflow continues to lagoon #2, where a smaller amount of gas is collected from five floating covers. The manure water that remains after digestion is then pumped from the second lagoon to cropland, where it is mixed with surface or groundwater and applied at agronomic rates as fertilizer for crops of corn, wheat, or alfalfa.

Lagoon #1 is fed once daily (taking approximately four hours) with flushed-manure slurry, and maintained at ambient temperatures. The dimensions of lagoon #1 are 1,100' × 220' × 18' deep. The lagoon is covered by a film of high density polyethylene (HDPE) material that is 60 mil thick. The cover is solidly anchored to the sides, having been folded into the surrounding trench and covered with concrete and earth. The anaerobic digester has an estimated hydraulic retention time of 67 days. A system of sand-filled HDPE pipes floats on the cover to partition the cover into cells. This allows for rainwater removal and helps direct biogas to the perimeter where the main gas collection pipe is located. Corrugated pipe extends around the perimeter, under the cover, to provide a pathway for the biogas to flow to the point of collection at the north pump house.

Overflow from lagoon #1 travels to lagoon #2. The dimensions of lagoon #2 are 1,100' × 220' × 15' deep. This lagoon is partially covered with five floating covers that measure 300' × 155' in total. The five floating covers atop this lagoon are made of 45 mil polyethylene and are installed to allow for fluctuating water levels resulting from rain or irrigation. Gas collection is accomplished by floating corrugated pipe under each cover. Gas flows to the collection point at the south pump house, where it mixes with the gas from lagoon #1 and is pumped one and one-half miles to the dairy.

Produced biogas is metered at the pump houses located on each lagoon. The collected biogas travels one and one-half miles to the dairy through an underground pipeline with water traps that expel much of the moisture and impurities from the gas. Excess gas flows through a relief valve and then to a flare located at the generation area.

At the dairy, the gas flows to four Cat G342 engines, each with a capacity of 125 kW for a total capacity of 500 kW. September-November 2005, only two engine-generators (at 125 kW each) were running on a consistent basis. Beginning in November 2005, the third and fourth engine-generators were brought on line. Electricity flows from the generators to the switchgear and utility interconnection facility adjacent to the engine room. Electricity generated by the system is used at the dairy. Any net generation is sent to the local utility for partial credit under net metering provisions.

Engine cooling is provided by a propeller pump located on a cistern, which receives its water from the milk refrigeration units. This water is then circulated through a shell and tube-type heat exchanger and back to the cistern for use in cow washing and barn cleaning.

Project #238: Lourenco Dairy

Project #238	**Lourenco Dairy**
Contact	Steve Lourenco
City, County	Tulare, Tulare County
General System Information	
Operational date:	April 2006 project complete but not operational
Reporting period:	April 2006 – June 2006
Herd size:	1,390 lactating; 150 dry; 1,100 heifers and calves
System type:	Covered lagoon (system refurbishment)
Dimensions:	1,100 × 220 × 18 ft. deep
Project history:	• Application submitted September 2002 • Approved for funding January 2003 • Complete April 2006 but not operational
Designer/Installer:	Sharp Energy
Generator nameplate capacity:	150 kW
Engine make/model:	Caterpillar 353
System Costs	
Estimated costs:	$229,557 for refurbishment
Actual costs:	$230,657 for refurbishment $142,255 in initial costs (pump, design, 6 floating covers, engine-generator, misc. parts and gas lines)
Operation & maintenance:	$500 per month
DPPP funding:	$114,779 (buydown)
Other funding:	None reported
Unexpected costs:	
Manure Collection and Handling	
Manure collection:	Flush system
Digester feeding mode:	Intermittent – 6 times per day
Digester inflow:	93,000 gallons per day
Retention time:	53 days

Project #238 (continued)	Lourenco Dairy
System Performance	
Biogas Production:	
Average per month (cubic feet)	Unavailable; currently flaring all biogas produced. No flare meter installed.
Average per day (cubic feet)	Unavailable; currently flaring all biogas produced. No flare meter installed.
Per cow (cubic feet per day)	Unavailable; currently flaring all biogas produced. No flare meter installed.
Estimated biogas flared	Unavailable. No flare meter installed.
Electrical Production:	
Generator nameplate capacity (kW)	150 kW
Generator operation (average hours/day) and actual generation (% of capacity)	0 hours/day; 0%
Average per month (kWh)	0
Average per day (kWh)	0
Total per cow (kWh/day/cow)	0
Energy Usage and Utility Information	
Utility Company:	Southern California Edison (SCE)
Average Energy Usage:	
Prior to installation (kWh per month)	45,698 kWh per month
Study period (kWh per month)	Producing no electricity. Utility bills not available for analysis.
Net metering?	Not currently
Use of generated power:	None currently
Estimated Savings	
From on-farm offset:	None
From net generation:	None
Thermal savings from recovered heat?	None
Other benefits:	None reported
Estimated Simple Payback Period (based on final costs for refurbishment):	Unavailable
Estimated Simple Payback Period (based on final costs for existing and refurbishment):	Unavailable

Project #238 (continued)	Lourenco Dairy
Obstacles, Dairy Owner Feedback and Suggestions	
Major obstacles faced:	• Low milk prices late 2001-mid 2003 • Obtaining interconnection permit • Net metering legislation • Construction related delays • System performance
Dairy owner feedback: Ranked 1-4, with 1=poor and 4=excellent; na=no answer	Ease in operating systems: .... na Advantages gained for manure mgt: .... 3 Odor control benefits: .... 3 Reduction in water usage: .... 1 Addresses electrical issues: .... na Overall satisfaction: .... na
Suggestions for improvements and/or lessons learned:	
Recent Developments	
Additional costs incurred (not included in actual costs above):	None reported
Significant changes implemented:	In process of replacing governor/controller on engine
Significant changes planned:	None reported
Recent operational problems:	• Heavy rains caused a low spot in gas lines allowing water to condense and settle in the low spots • Erratic functioning of engine control system causing RPM to go up and down. Determined the governor/controller was faulty and needed to be replaced. • Digester filling with solid manure. Liquid manure is creating channels around the floating covers. • Generator model temperamental in interfacing with the utility grid.
General System Overview	

The milking parlor/sprinkler pen and feed aprons are all flushed with either fresh or recycled water two to three times daily. The dairy does not reuse flush water from the lagoon. Instead water that is used to cool the milk, wash the milk barn, and wash the cows prior to milking is recycled to flush the feed aprons. This equates to a total of 93,000 gallons of water that is either fresh or recycled being added to the digester each day. In addition, there is one lane that is flushed once per week with an additional 8,000 gallons of water.

The flushed liquid enters a small settling pond to remove any sand that may be in the flush water and is then lifted over an inclined screen separator to remove some additional manure solids. The separated solids are used as bedding or for soil amendment on the dairy's cropland.

The screened liquid is discharged to the existing lagoon measuring 1100 × 90 × 10-ft deep. The lagoon is fed intermittently six times a day. The hydraulic retention time (HRT) of the lagoon digester is an estimated 53 days. The screened liquid is introduced into the lagoon at an inlet structure located about 190 ft from one end of the lagoon. The liquid manure travels along the length of the lagoon to the outlet located on the other side of the lagoon. The lagoon temperature is not controlled.

Project #238 (continued)	Lourenco Dairy

***General System Overview** (continued)*

At the time of grant application, approximately 37,800 sq. ft (~38%) of the lagoon surface was covered. The purpose of applying for grant funds was to convert the existing, non-operational, partially covered lagoon to an anaerobic digester to produce methane to be used to power an existing synchronous generator. With the addition of the new cover panels, it is estimated that approximately 73% of the surface of the lagoon is now covered. One end of the lagoon was not covered, as this area is not expected to produce appreciable amounts of biogas.

Digester effluents are piped to the final storage lagoon called the "centrifuge lagoon". From here, digester effluent is used for irrigation where it is applied to cropland at agronomic rates.

The covered lagoon is expected to operate as an anaerobic digester producing biogas with an expected methane content of 70%. The dairy owner is currently flaring all biogas produced. A flare meter is not installed and therefore biogas production figures are unavailable. All biogas produced will eventually be used by the existing 150 kW-capacity Caterpillar 353 engine-generator to produce power for on farm use. The current design allows the biogas that is not used in the engine-generator to be circulated back to the covered lagoon as storage for when the gas can be used.

In the initial design specifications, it was estimated that the digester would produce 344,553 cubic feet of biogas per day. However, technical due diligence review suggested an estimated 53,250 cubic feet per day of biogas would be achievable assuming a biogas methane content of 70%.

At this time no biogas is utilized by the engine-generator to produce electricity. In the grant application, an estimated electricity production of 3,222 kWh/day from a total available capacity of 150 kW was expected. Given an estimated average of 3,222 kWh/day, it was assumed that the engine-generator would operate at about 89% capacity.

6. Case Studies: Plug Flow Digesters

Project #249: Eden-Vale Dairy

Project #249	Eden-Vale Dairy
Contact	Jake DeRaadt
City, County	Lemoore, Kings County
General System Information	
Operational date:	January 2006
Reporting period:	January – June 2006 (6 months)
Herd size:	800 lactating; 150 dry; 150 heifers
System type:	Plug flow (new system)
Dimensions:	30 × 150 × 14 ft. deep
Project history:	• Application submitted September 2003 • Approved for funding November 2003 • Operational January 2006
Designer/Installer:	RCM Digesters
Generator nameplate capacity:	180 kW
Generator make/model:	Caterpillar 3406
System Costs	
Estimated costs:	$661,923
Actual costs:	$802,810
Operation & maintenance:	$1,500 per month
DPPP funding:	$300,000 (buydown)
Other funding:	None reported
Unexpected costs:	• Increase in material and construction costs during period between project planning and actual construction. • In addition to system costs, the dairy owner estimated personal and employee labor costs of approximately $50,000. This is not included in actual costs above.
Manure Collection and Handling	
Manure collection:	Scrape and one trailer-mounted vacuum units
Digester feeding mode:	Intermittently (2X per day)
Digester inflow:	15,000 gallons per day
Retention time:	22 days

Project #249 (continued)	Eden-Vale Dairy
System Performance	
Biogas Production:	
Average per month (cubic feet)	1,218,238 utilized by engine-generator
Average per day (cubic feet)	40,360 utilized by engine-generator
Per cow (cubic feet per day)	50 utilized by engine-generator
Estimated biogas flared	Flaring does occur. No metered figures and no estimate provided.
Electrical Production:	
Generator nameplate capacity (kW)	180 kW
Generator operation (average hours/day) and actual generation (% of capacity)	18 hours/day; 29%
Average per month (kWh)	37,764 kWh
Average per day (kWh)	1,253 kWh
Total per cow (kWh/day/cow)	1.57 kWh
Energy Usage and Utility Information	
Utility Company:	Pacific Gas & Electric (PG&E)
Average Energy Usage:	
Prior to installation (kWh per month)	23,314 per month average for all dairy account on NEMBIO billing
Study period (kWh per month)	24,542 per month average for all dairy account on NEMBIO billing
Net metering?	Yes – 9 dairy meters included Avg. net generation on parent: 34,840 kWh per month Avg. net consumption on parent: 24,542 kWh per month
Use of generated power:	Very little offset of on farm usage (1 meter is connected to the engine-generator that serves the separator, a well, freestall lights, a manure pump and the generator load); mainly net metering; no power purchase agreement
Estimated Savings	
From on-farm offset:	None for report period, however the dairy owner is considering connecting more load to the engine-generator. Actual savings are unknown, however using historical usage figures, it is estimated that savings due to on-farm usage of the main dairy accounts could average $2,644 per month, assuming a $0.07 per kWh value. This would bring total monthly savings (on farm offset plus net metering) to an estimated $3,595. Estimates increase during high usage months and if system was running at full capacity.

Project #249 (continued)	Eden-Vale Dairy
Estimated Savings *(continued)*	
From net generation:	• Monthly generation credits averaged $952 per month (reaching $1,420 in June 2006); however only those credits that can be used towards unbilled generation charges are realized savings. Excess generation credits are zeroed out at end of 12-month period. • Realized savings averaged $734 per month; however, larger kWh usage during summer months should bring this closer to the generation credit figure above. • Savings est. at generation rate of $0.03/kWh • On average, $218 per month in excess generation credits were forfeited • Again, it should be noted that the dairy owner has chosen not to run the system at full capacity due to the small compensation for generated power.
Thermal savings from recovered heat?	• Recovered heat used to heat digester • Considering use of recovered heat to produce hot water for use on dairy.
Other benefits:	None reported
Estimated Simple Payback Period (based on final costs):[8]	With no grant funding: 70.3 years After DPPP funding: 44.0 years After all grant funding: 44.0 years
Estimated Simple Payback Period (based on final costs and assuming offset of on farm power):	With no grant funding: 18.6 years After DPPP funding: 11.7 years After all grant funding: 11.7 years
Obstacles, Dairy Owner Feedback and Suggestions	
Major obstacles faced:	• Low milk prices late 2001-mid 2003 • Obtaining Rule 21 interconnection permit • Net metering legislation • Construction related delays • Obtaining necessary permits
Dairy owner feedback: Ranked 1-4, with 1=poor and 4=excellent	Ease in operating systems: 2.83 Advantages gained for manure mgt: 3.5 Odor control benefits: 2.5 Reduction in water usage: 2.0 Addresses electrical issues: 1.0 Overall satisfaction: 2.5
Suggestions for improvements and/or lessons learned:	• Costs to run engine-generator are not currently offset by benefits of producing power for net metering purposes • Operational expenses are higher than anticipated and electrical generation value is much lower. • Plans on additional training on machinery for staff • Hopeful that power purchase agreements will someday be available

[8] Simple payback does not consider the time value of money, inflation, or operation and maintenance costs

Project #249 (continued)	Eden-Vale Dairy
Recent Developments	
Additional costs incurred (not included in actual costs above):	Approximately \$2,000 on engine and control repairs.
Significant changes implemented:	None reported
Significant changes planned:	• Currently, dairy owner is not running the system at capacity (i.e. not all the manure enters the digester and not all the biogas is used by the generator). There is no incentive to produce excess power for none to little compensation. • Owner is considering connecting more of the dairy's load directly to the engine-generator.
Recent operational problems:	• Separator un-operational for several months • Necessary valve repairs • Blown muffler • Problems with gas solenoid • Power outages

General System Overview

Lactating cows are housed primarily in freestall barns approximately 22 hours each day, where they have access to attached dry lots approximately 8 hours each day in dry months. They spend the other two hours in the milking parlor. The dry cows and heifers spend approximately 16 hours in drylots and 8 hours in feed aprons. Only manure from the lactating cows is currently fed to the digester.

Separate from the digester project, the dairy owner converted one of the large loafing barns into an additional free stall barn with attached dry lots. This conversion allowed for an additional two tanker loads per day of manure to be collected for the digester.

Manure from the feed aprons and freestall alleys is collected with a vacuum scrape collection system. Scraping is conducted 6 to 7 times daily, and manure is collected with one trailer-mounted Loewen 2,500 gallon capacity vacuum unit. It is estimated that approximately 75% to 80% of the available manure is collected in these areas. The remainder, dry lot manure is not collected for the digester. An estimated 15,000 gallons of manure per day is transferred to the digester.

In order to maintain optimum solids content, water from the parlor, wash area, and holding yard is plumbed to by-pass the digester system and is deposited directly into a storage pond. When needed, the manure can be diluted with this water to achieve the targeted 12% to 13% solids entering the digester.

The undiluted manure is deposited directly into an influent collection tank at the input end of the digester and is gravity fed by displacement over a weir into the digester vessel.

The concrete mesophilic (35°C or 95°F) plug flow digester has a hydraulic retention time of about 20 days. The digester is rectangular and measures 30' wide × 150' long. The depth at the center of the digester is 14 feet. The digester is covered with a flexible, impervious top. Approximately 15,000 gallons of manure slurry are fed to the digester per day. To enhance decomposition of the manure, waste heat from the engine is used to heat the digester to approximately 100°F. A heat exchanger located on the engine-generator produces hot water, which is circulated through heat exchange lines in the digester. This raises the digester temperature to allow greater gas production. The engine-generator is run continuously, unless shutdowns are necessary for maintenance, to maintain the digester temperature.

Project #249 (continued)	Eden-Vale Dairy

***General System Overview** (continued)*

Biogas collected from the digester is piped underground to the engine room that is part of a 30' × 50' combined engine room and shop building. The produced biogas is currently used to power the 180-kW capacity IC Caterpillar 3406 engine. During the study period the system produced far more biogas and electricity than could be used for dairy operations connected to the engine. The dairy owner reports having no incentive to generate surplus electricity for which he would have received no compensation. Therefore, excess gas not used by the engine-generator was flared during this period. The dairy owner is considering the possibility of setting up his system so that maximum dairy load is connected to the generator in order to further reduce utility charges.

As the digester is fed, effluent is hydraulically displaced. Digested manure flows out of the digester into a concrete effluent storage tank from which it is pumped to a screw press separator to separate fibers from liquids. The effluent tank is protected by emergency overflow pipe that flows by gravity to the storage lagoon. The separated solids are composted and used as bedding for the cows in the freestall barns. The liquid effluent gravity flows to a storage pond where it is then applied as irrigation to surrounding cropland at agronomic rates.

Project #225: Koetsier Dairy

Project #225	Koetsier Dairy
Contact	Ron Koetsier
City, County	Visalia, Tulare County
General System Information	
Operational date:	October 2005
Reporting period:	October 2005 – July 2006 (10 months)
Herd size:	1,266 lactating; 147 dry; 852 heifers; 20 bulls
System type:	Plug flow (system refurbishment)
Dimensions:	30 × 180 × 16 ft. deep
Project history:	• Application submitted December 2001 • Approved for funding March 2002 • Operational October 2005
Designer/Installer:	RCM Digesters
Generator nameplate capacity:	(2) 135 kW capacity generators for a total of 260 kW; only one is currently used
Engine make/model:	Caterpillar G342
System Costs	
Estimated costs:	$381,850 for refurbishment of non-operational system
Actual costs:	• $363,087 for refurbishment of non-operational system • $998,000 in initial costs for original turn-key digester system that included: digester tank, electrical work, interconnection equipment, pumps, separators, one engine-generator (refurbished through DPPP), mixing pit, all concrete work, water storage tank, etc.
Operation & maintenance:	$2,250 per month
DPPP funding:	$190,925 (incentive payments)
Other funding:	None reported
Unexpected costs:	Increase in material and construction costs during period between project planning and actual construction
Manure Collection and Handling	
Manure collection:	Scrape and one trailer-mounted vacuum units
Digester feeding mode:	Intermittently (2X per day)
Digester inflow:	30,000 gallons per day
Retention time:	22 days

Project #225 (continued)	Koetsier Dairy
System Performance	
Biogas Production:	
Average per month (cubic feet)	1,344,400 utilized by engine-generator
Average per day (cubic feet)	44,193 utilized by engine-generator
Per cow (cubic feet per day)	35 utilized by engine-generator
Estimated biogas flared	15-40%
Electrical Production:	
Generator nameplate capacity (kW)	(2) 135 kW capacity generators for a total of 260 kW; however only one was used during study period (see utility discussions below)
Generator operation (average hours/day) and actual generation (% of capacity)	22 hours/day; 24%
Average per month (kWh)	44,991
Average per day (kWh)	1,687
Total per cow (kWh/day/cow)	1.33
Energy Usage and Utility Information	
Utility Company:	Southern California Edison (SCE)
Average Energy Usage:[9]	
Prior to installation (kWh per month)	55,265 per month average for main ("parent") dairy account
Study period (kWh per month)	11,150 per month average for main ("parent") dairy account[10]
Net metering?	Yes – 2 dairy meters included Avg. net generation on parent: 12,123 kWh per month Avg. net consumption on parent: 11,150 kWh per month
Use of generated power:	Offset on farm usage; some net metering; no power purchase agreement

[9] Potential billing issues March 2006-July 2006 are currently under review by the dairy owner and SCE. Therefore, October 2005-February 2006 utility bills and net generation figures are used for analysis purposes.
[10] Any changes year-to-year would not only capture offset due to generated energy used on farm but also any changes in the daily operations such as cow numbers, weather related energy usage fluctuations, etc.

Project #225 (continued)	Koetsier Dairy
Estimated Savings	
From on-farm offset:	• $24,684 per year or $2,057 per month avg. • Savings est. at energy rate of $0.06/kWh • Demand charges have not been subsequently reduced. Use of on-farm generation cannot be valued at full retail rate.
From net generation:	• Monthly generation credits averaged $38 per month (varied greatly by month); however, only those credits that can be used towards unbilled generation charges are realized savings. Excess generation credits are zeroed out at end of the 12-months. • Realized savings from net metering averaged $0.35 per month. • Net generation credits valued at an average $0.03/kWh • On average, $37 per month in excess generation credits forfeited.
Thermal savings from recovered heat?	• Recovered heat used to heat digester • Considering use of recovered heat to produce hot water for use on dairy.
Other benefits:	• None reported during study period • Recently applied to the Chicago Climate Exchange (CCX) to sell greenhouse gas credits. Therefore, the dairy owner will be making efforts to optimize his biogas production and will be carefully metering his biogas quantity and quality. Because of this, system performance figures for the coming year will likely reflect optimal operation of the system. Potential revenues to be generated are not yet known.
Estimated Simple Payback Period (based on final costs for refurbishment):[11]	With no grant funding: 15.0 years After DPPP funding: 7.1 years After all grant funding: 7.1 years
Estimated Simple Payback Period (based on final costs for existing and refurbishment):	With no grant funding: 56.2 years After DPPP funding: 48.3 years After all grant funding: 48.3 years
Obstacles, Dairy Owner Feedback and Suggestions	
Major obstacles faced:	• Low milk prices late 2001-mid 2003 • Obtaining Rule 21 interconnection permit • Net metering legislation • Replacement of generator motor December 2004 caused initial delays
Dairy owner feedback: Ranked 1-4, with 1=poor and 4=excellent	Ease in operating systems: 2 Advantages gained for manure mgt: 3 Odor control benefits: 3 Reduction in water usage: 4 Addresses electrical issues: 1 Overall satisfaction: 2

[11] Simple payback does not consider the time value of money, inflation, or operation and maintenance costs

Project #225 (continued)	Koetsier Dairy
***Obstacles, Dairy Owner Feedback and Suggestions** (continued)*	
Suggestions for improvements and/or lessons learned:	• System is designed to work as a whole, and efficiency of the entire system can be affected by a small problem in one of the components. • The vacuum truck is a labor intensive process. Would prefer a mechanized scrape system.
Recent Developments	
Additional costs incurred (not included in actual costs above):	Remodeling the input system at a cost of $7,500
Significant changes implemented:	None reported
Significant changes planned:	• Will install fans August 2006 • Have begun work to remove the input pipe and convert to a tank. Work expected to be complete by August 10, 2006. This will allow for much faster loading of manure into the digester.
Recent operational problems:	None reported
General System Overview	

The lactating cows are housed primarily in freestall barns where they spend approximately 21 hours each day. They spend the other three hours in the milking parlor. The dry cows and heifers spend approximately 12 hours in drylots and 12 hours in feed aprons.

The dairy previously operated on a flush system. In order to increase biogas production, the dairy converted to a scrape system as part of this refurbishment project. The feed aprons and freestall alleys are now scraped twice daily. One truck-mounted Loewen 3,750 gallon capacity vacuum unit is used to collect the manure. Undiluted manure is dumped directly into the digester.

The concrete mesophilic (35°C or 95°F) plug flow digester has a hydraulic retention time of about 22 days. The digester has a V-shaped bottom, and measures 30 wide × 180 long. The depth at the center of the digester is 16 feet, while measuring 12 feet deep at the sides. The digester is covered with a flexible, impervious top. Approximately 30,000 gallons of manure slurry are fed to the digester per day. To enhance decomposition of the manure, waste heat from the engine is used to heat the digester to approximately 100°F. A heat exchanger located on the engine-generator produces hot water, which is circulated through heat exchange lines in the digester. The engine-generator is run continuously, unless shutdowns are necessary for maintenance, to maintain the digester temperature.

Biogas is transmitted through 150 feet of pipeline to the generator building located next to the digester. The produced biogas is currently used to power one of the available 135-kW capacity Caterpillar G342 engine-generators. During the study period, the second 135-kW capacity Caterpillar G342 engine-generator was not utilized. The dairy owner reports having no incentive to power the second engine-generator in order to produce surplus electricity for which he would have received little to no compensation. Therefore, the dairy owner underfeeds the digester and flares the gas that is not used by the one engine.

Digested manure flows out of the digester into a concrete effluent storage tank from which it is pumped to a screw press separator. The separated solids are composted and used as bedding for the cows in the freestall barns. The liquid effluent gravity flows to a storage pond where it is then applied as irrigation to surrounding cropland at agronomic rates.

Project #230: Meadowbrook Dairy

Project #230	Meadowbrook Dairy
Contact	Ed Imsand
City, County	El Mirage, San Bernardino
General System Information	
Operational date:	October 2004
Reporting period:	October 2004 – September 2005 (12 months)
Herd size:	2,093 lactating; 330 dry; 120 heifers; 628 calves; 23 bulls
System type:	Plug flow (new system)
Dimensions:	32 × 156 × 14 ft. deep
Project history:	• Application submitted December 17, 2001 • Approved for funding March 2002 • Operational August 1, 2004
Designer/Installer:	RCM Digesters
Generator nameplate capacity:	160 kW
Engine make/model:	Caterpillar 3406TA
System Costs	
Estimated costs:	$524,898
Actual costs:	$720,605
Operation & maintenance:	$560 per month
DPPP funding:	$262,449 (buydown)
Other funding:	$200,000 USDA/NRCS/EQIP
Unexpected costs:	Additional material (primarily concrete) & construction expenses
Manure Collection and Handling	
Manure collection:	Scrape and 2 trailer-mounted vacuum units
Digester feeding mode:	Intermittently (1-6X per day)
Digester inflow:	20,242 gallons per day
Retention time:	19 days

Project #230 (continued)	Meadowbrook Dairy
System Performance	
Biogas Production:	
Average per month (cubic feet)	2,446,558 utilized by engine-generator
Average per day (cubic feet)	80,507 utilized by engine-generator
Per cow (cubic feet per day)	38 utilized by engine-generator
Estimated biogas flared	Very little; only when system is down for maintenance or repair
Electrical Production:	
Generator nameplate capacity (kW)	160
Generator operation (average hours/day) and actual generation (% of capacity)	23 hours/day; 78%
Average per month (kWh)	91,553
Average per day (kWh)	3,015
Total per cow (kWh/day/cow)	1.44
Energy Usage and Utility Information	
Utility Company:	Southern California Edison (SCE)
Average Energy Usage:	
Prior to installation (kWh per month)	72,250 per month average for main ("parent") dairy account; 89,316 for all dairy accounts
Study period (kWh per month)	18,372 per month average for main ("parent") dairy account[12]; 36,373 for all dairy accounts
Net metering?	Yes – 4 dairy meters included Avg. net generation on parent: 28,642 kWh per month Avg. net consumption on parent: 18,372 kWh per month
Use of generated power:	Offset on farm usage; some net metering; no power purchase agreement

[12] Any changes year-to-year would not only capture offset due to generated energy used on farm but also any changes in the daily operations such as cow numbers, weather related energy usage fluctuations, etc.

Project #230 (continued)	Meadowbrook Dairy
Estimated Savings	
From on-farm offset:	• $44,726 per year or $3,727 per month. Estimated at energy rate of $0.06/kWh • Demand charges have not been subsequently reduced. Use of on-farm generation cannot be valued at full retail rate.
From net generation:	• Monthly generation credits averaged $3,890 per year or $324 per month estimated at generation rate of $0.04/kWh • No excess generation credits were forfeited
Thermal savings from recovered heat?	• Recovered heat used to heat digester • Considering use of recovered heat to produce hot water for use on dairy.
Other benefits:	None reported
Estimated Simple Payback Period (based on final costs):[13]	With no grant funding: 14.8 years After DPPP funding: 9.4 years After all grant funding: 5.3 years
Obstacles, Dairy Owner Feedback and Suggestions	
Major obstacles faced:	• Low milk prices late 2001-mid 2003 • Obtaining necessary building permits • Obtaining Rule 21 interconnection permit • Net metering legislation • Initial complications with electrical and control system
Dairy owner feedback: Ranked 1-4, with 1=poor and 4=excellent	Ease in operating systems: 2.92 Advantages gained for manure mgt: 3.75 Odor control benefits: 3.17 Reduction in water usage: 3.50 Addresses electrical issues: 3.33 Overall satisfaction: 3.08
Suggestions for improvements and/or lessons learned:	• Need a simplified control system for engine-generator. • Need to process input material better to remove sand and foreign objects before pumping into digester.

[13] Simple payback does not consider the time value of money, inflation, or operation and maintenance costs

Project #230 (continued)	Meadowbrook Dairy
Recent Developments	
Additional costs incurred (not included in actual costs above):	Rebuilt engine because of H_2S problems at 6,000 hours, at a cost of \$20,000. Currently changing oil every week at a cost of \$255 for oil.
Significant changes implemented:	In process of adding calf flush facilities involving 3 more pumps, 1 separator and air compressor.
Significant changes planned:	• Plans to add additional engine-generator when financially feasible. Will incorporate whey cake from local cheese manufacturer to add additional 60,000 cubic feet of biogas/day. • Researched many things such as adding a scrubber to clean up biogas but still waiting on proven method to decrease H_2S.
Recent operational problems:	Bauer Press separator is difficult to keep running. Plastic, twine, and other foreign objects cause pump problems. Foaming and bag tearing has been an issue.

General System Overview

The dairy is an open pen drylot facility. The lactating cows are housed primarily in drylot pens where they spend approximately 21 hours each day. The other three hours are spent in the milking parlor. The dry cows are housed in drylot pens where they typically spend half their time on the feed aprons.

On average, the dairy uses approximately 70,000 gallons per day of fresh water. The cows drink approximately 30,000 gallons daily, and the other 40,000 gallons are used in the dairy operation. This 40,000 gallons is used three different times. Initially, the water pre-cools the milk, is collected and used to wash the cows, and then is separated and either used to adjust the digester input or mixed with fresh water and used to irrigate cropland.

The feed aprons are scraped once daily. Two trailer-mounted vacuum units are used to collect the manure; one unit has a capacity of 2,400 gallons, the other holds 3,750 gallons. Manure from the feed pad is dumped into a mix tank for adjustment of digester-feed solids concentration. The manure is diluted with parlor wastewater down to 12% total solids. The dairy collects and processes through the digester approximately 40% of the manure and waste generated daily; the other 60% is collected from the drylot pens, composted, and managed separately.

A manure pump moves the mixed manure once a day to the 32 × 156 × 14- foot deep, concrete mesophilic (35°C or 95°F) plug flow digester having a hydraulic retention time of about 19 days. The digester is covered with a flexible, impervious top. Approximately 20,242 gallons per day are fed to the digester. To enhance decomposition of the manure, waste heat from the engine is used to heat the digester to approximately 101°F. The produced biogas is used to power a 160-kW capacity Caterpillar 3406TA engine.

Digested manure flows out of the digester into a concrete effluent storage tank from which it is pumped to a screw press separator. The separated solids are composted and shipped to the off-site farm. The dairy owner plans to mix the digested solids with green waste, possibly bark beetle pine, to be sold to a potting soil manufacturer. The liquid effluent gravity flows to a waste storage pond where it is then used for irrigation on surrounding cropland.

Project #226: Van Ommering Dairy

Project #226	Van Ommering Dairy
Contact	Rob Van Ommering
City, County	Lakeside, San Diego County
General System Information	
Operational date:	June 2005
Reporting period:	June 2005 – May 2006 (12 months)
Herd size:	480 lactating; 92 dry; 52 heifers; 66 calves; 27 bulls
System type:	Plug flow (new system)
Dimensions:	30 × 130 × 12 ft. deep
Project history:	• Application submitted December 2001 • Approved for funding March 2002 • Operational June 2005
Designer/Installer:	RCM Digesters
Generator nameplate capacity:	130 kW
Engine make/model:	Caterpillar 3406
System Costs	
Estimated costs:	$489,284
Actual costs:	$836,838
Operation & maintenance:	$1,500 per month
DPPP funding:	$244,642 (buydown)
Other funding:	$150,000 USDA/NRCS/EQIP
Unexpected costs:	Increased costs for building supplies such as lumber and concrete, $33,000 for interconnection with utility and $20,000 for county permits.
Manure Collection and Handling	
Manure collection:	Scrape and 1 trailer-mounted vacuum unit
Digester feeding mode:	Intermittently (1-6X per day)
Digester inflow:	• 2,857 gallons per day • Currently averaging 8,000 gallons per day due to completion of freestall barns
Retention time:	24 days

Project #226 (continued)	Van Ommering Dairy
System Performance	
Biogas Production:	
Average per month (cubic feet)	1,025,296 cubic feet utilized by engine-generator
Average per day (cubic feet)	33,935 cubic feet utilized by engine-generator
Per cow (cubic feet per day)	70.7 cubic feet utilized by engine-generator
Estimated biogas flared	40-50%
Electrical Production:	
Generator nameplate capacity (kW)	130 kW
Generator operation (average hours/day) and actual generation (% of capacity)	19 hours/day; 43%
Average per month (kWh)	40,529 kWh
Average per day (kWh)	1,341 kWh
Total per cow (kWh/day/cow)	2.79 kWh
Energy Usage and Utility Information	
Utility Company:	San Diego Gas & Electric (SDG&E)
Average Energy Usage:	
Prior to installation (kWh per month)	32,260 per month average for all accounts
Study period (kWh per month)	28,770 per month average for all accounts
Net metering?	Yes – 7 meters included Avg. net generation: 36,832 kWh per month
Use of generated power:	Only net metering during study period; no power purchase agreement. In process of connecting load directly for on-farm use of generated power.
Estimated Savings	
From on-farm offset:	None during study period. See recent developments below.
From net generation during relevant period February 2005-January 2006:	• $24,613 per year or $2,051 per month avg. • Savings estimated at generation rate of $0.05/kWh • A total of $1,488 of unused generation credits were forfeited for the period • System was not run at capacity due to the fact that there was no compensation for excess generated power
Thermal savings from recovered heat?	• Recovered heat used to heat digester • Considering use of recovered heat in the future
Other benefits:	None reported

Project #226 (continued)	Van Ommering Dairy
Estimated Savings ***(continued)***	
Estimated Simple Payback Period (based on final costs):[14]	With no grant funding: 34.0 years After DPPP funding: 24.1 years After all grant funding: 18.0 years Note: though no estimates are currently available, monthly savings will increase due to recent implementation of on farm use of generated power. This will reduce the payback period.
Obstacles, Dairy Owner Feedback and Suggestions	
Major obstacles faced:	• Low milk prices late 2001-mid 2003 • Obtaining necessary permits (2 ½ year delay) • Net metering legislation • Weather related delays
Dairy owner feedback: Ranked 1-4, with 1=poor and 4=excellent	Ease in operating systems: 1.92 Advantages gained for manure mgt: 3.00 Odor control benefits: 4.00 Reduction in water usage: 2.00 Addresses electrical issues: 3.00 Overall satisfaction: 2.91
Suggestions for improvements and/or lessons learned:	• Connect dairy load to engine-generator directly • Generator was not run at capacity because there was no compensation available for excess generated power. This greatly reduced the financial feasibility of the project • Power purchase agreements with the utility should be available
Recent Developments	
Additional costs incurred (not included in actual costs above):	Additional receiving tank at cost of $30,000
Significant changes implemented:	• Additional receiving tank installed May 2006 • Flare meter installed June 2006. • Construction of three freestall barns complete August 1, 2006. This is currently increasing digester inflow by an estimated 8,000 gallons per day and has increased scraping frequency to 3 times per week. • Load from 2 wells, 1 shop and 1 house were connected to the engine-generator output
Significant changes planned:	• Plans underway to connect load to the engine-generator. Newly constructed freestall barns with lighting will be connected by August 15, 2006 and fans will be connected by June 1, 2007.
Recent operational problems:	April and May 2006, additional downtime was experienced due to the following: exhaust flex line cracked, starter solenoid replaced, fuel governor problems, sensor wire came loose and a grid surge.

[14] Simple payback does not consider the time value of money, inflation, or operation and maintenance costs

Project #226 (continued)	Van Ommering Dairy

General System Overview

During the study period, the lactating cows were housed in drylot pens where they spent approximately 21 hours each day. The other three hours are spent in the milking parlor. Three freestall barns under construction during the study period were completed on August 1, 2006. These freestall barns will now house the lactating cows. The dry cows are housed primarily in drylot pens where they typically spend half their time on the feed aprons. Some dry cows are also kept on surrounding pasture.

For the study period, inflow to the digester came primarily from the feed aprons. The feed aprons are scraped approximately two times per week. A trailer-mounted vacuum unit with a capacity of 2,500 gallons is currently used to collect the manure used for the plug flow system. However, due to completion of the freestall barns, it is estimated that inflow to the digester will increase from the estimated 2,857 gallons per day to approximately 8,000 gallons per day.

Manure is dumped into a 30,000 gallon mix tank for adjustment of digester-feed solids concentration. The manure is diluted with parlor wastewater down to 12% total solids.

A manure pump moves the mixed manure intermittently (1-6 times per day) to a 30 × 130 × 12 foot deep, concrete mesophilic (35°C or 95°F) plug flow digester having a hydraulic retention time of approximately 24 days. The digester is covered with a flexible, impervious top. To enhance decomposition of the manure, waste heat from the engine is re-circulated through the digester's heating coils to heat the digester to approximately 100°F.

The produced biogas is used to power a 130-kW capacity Caterpillar 3406 engine.

Digested manure flows out of the digester into a concrete effluent storage tank located between the digester and mixing tank. From there, it is pumped to a screw press separator where most of the liquid is extracted. Currently, the separated solids are composted for bedding. Composted solids may also eventually be made available for landscaping sales. The liquid effluent flows to a storage pond for additional treatment before being used for irrigation on surrounding pasture.

7. Case Study: Modified Mix Plug Flow Digester

Project #248: Inland Empire Utilities Agency

Project #248	**Inland Empire Utilities Agency (IEUA)**
Contact	Laura Cashion
City, County	Chino, San Bernardino County
General System Information	
Operational date:	April 2006
Reporting period:	April – June 2006
Herd size:	Collected manure from 6 dairies with a combined population of approximately 9,843 cows including 7,931 lactating, 1,431 dry milk cows and 481 heifers
System type:	Modified Mix Plug Flow (modification of existing system)
Dimensions:	195 × 60 × 16 ft. deep
Project history:	• Application submitted June 2003; revised September 2003 • Approved for funding November 2003 • Operational April 2006
Designer/Installer:	IEUA

Generator nameplate capacity:	• Engine-generators at Desalter facility have a total electricity generating capacity of 1,800 kW.
	• RP-5 has a total electricity generating capacity of 943 kW based on digester/biogas production capacity.
	   ▪ RP-5 Phase 1A operated at 380 kW capacity prior to this grant.
	   ▪ RP-5 Phase 1B funded by this grant included system enhancements to expand capacity by a total of 563 kW, bringing total RP-5 capacity up to 943 kW.

Engine make/model:	Engine-generator #1 Waukesha 7042 (1,000 kW capacity) Engine-generator #2 Waukesha 5790 (850 kW capacity

Project #248 (continued)	Inland Empire Utilities Agency (IEUA)
System Costs	
Estimated costs for Phase 1B expansion:	$1,546,350 for modification and expansion of existing digester system at RP-5 facility
Actual costs for Phase 1B expansion:	$3,551,448
Operation & maintenance:	$117,059 per month
DPPP funding:	• $773,175 (incentive payment) • Paid at 5.7 cents per kWh above an expected baseline production of 2,829,480 kWh per year or 380 kW already achieved prior to Phase 1B expansion
Other funding:	$175,000 from California Energy Commission for purchase of (4) vacuum tank trailers
Unexpected costs:	• Construction costs nearly tripled between time of grant application and construction
Manure Collection and Handling	
Manure collection:	Scrape and HoneyVac vacuum tanker used at each dairy facility. Manure is discharged to a small holding tank for pickup and transport to the RP-5 digester by a vacuum nurse tanker
Digester feeding mode:	Continuous
Digester inflow:	34,532 gallons per day during study period
Retention time:	15-21 days
System Performance	
Biogas Production from RP-5:	
Average per month, including flared amount (cubic feet)	3,490,969 cubic feet
Average per day, including flared amount (cubic feet)	113,189 cubic feet
Average per month biogas flared (cubic feet)	893,120 cubic feet per month
Electrical Production from RP-5:	
Generator nameplate capacity (kW)	• 943 kW total (see detailed explanation above) • Baseline capacity for RP-5 Phase 1A = 380 kW • Phase 1B expanded capacity = 563 kW
Generator operation (average hours/day) and actual generation (% of capacity)	11.15 hours/day; 18% of total available 943 kW capacity; 0% of Phase 1B 563 kW capacity
Average per month (kWh)	120,970 kWh
Average per day (kWh)	3,977 kWh
Total per day per cubic feet of biogas (kWh/day)	0.035 kWh

Project #248 (continued)	Inland Empire Utilities Agency (IEUA)
Energy Usage and Utility Information	
Utility Company:	Southern California Edison
Average Energy Usage:	
At Desalter facility (kWh per month)	1,095,796 per month
At RP-5 facility (kWh per month)	96,680 per month
Estimated offset at Desalter facility attributable to RP-5 Phase 1B expansion	None; system not running at full capacity and RP-5 electrical generation did not exceed Phase 1B baseline
Net metering?	No
Use of generated power:	Offset usage at Desalter facility; no offset at RP-5 facility
Estimated Savings	
RP-5 generation offset at Desalter savings (this can not be attributed to Phase 1B enhancements)	$117,996 per year or $9,833 per month average. Savings estimated at rate of $0.08/kWh
Potential RP-5 generation offset at Desalter facility savings if system reaches ***expected*** performance	$311,695 per year or $25,975 per month average. Savings estimated at rate of $0.08/kWh
From net generation:	Not applicable
Thermal savings from recovered heat?	• Yes, recovered heat used to heat digester • Estimated savings of $5,114 per month
Other benefits:	Tipping fees of $8.10 per load are charged to the participating dairies. Tipping fees amount to an average of $1,550 per month.
Estimated Simple Payback Period for Phase 1B (based on final costs and performance during study period):[15]	Undetermined, as RP-5 electrical production did not exceed Phase 1B baseline during study period
Estimated Simple Payback Period for Phase 1B (based on final costs and ***expected*** performance):	With no grant funding: 9.1 years After DPPP funding: 7.1 years After all grant funding: 6.6 years

[15] Simple payback does not consider the time value of money, inflation, or operation and maintenance costs

Project #248 (continued)	Inland Empire Utilities Agency (IEUA)
Obstacles, Dairy Owner Feedback and Suggestions	
Major obstacles faced:	• Project delays in order to implement a design/bid/build approach • Project delays due to design work • Project delays due to change of manure collection equipment • Weather related delays • Grit found in digester tank leading to total cleaning of tank
Feedback: Ranked 1-4, with 1=poor and 4=excellent	Ease in operating systems: .... 3 Addresses electrical issues: .... 3 Overall satisfaction: 3
Suggestions for improvements and/or lessons learned:	
Recent Developments	
Additional costs incurred (not included in actual costs above):	Cleaning out of digester tank at an estimated cost of $292,342
Significant changes implemented:	In May 2006, IEUA reported that the digester was still producing biogas with only 55-60% methane content, noting that operation at thermophilic range was expected by June 2006. Although the digester was not yet operating at full capacity or temperature, for DPPP reporting purposes, an official startup date of April 1, 2006 was set to allow a period of data collection for reporting purposes.
Significant changes planned:	• Phase 2 expansion will allow for treatment of an additional 300 wet tons of dairy manure and 90 wet tons of food waste. Expansion expected to provide an additional 1,500 kW of generated power by December 2006. • Currently pays hauling fees to have separated solids removed. Researching other applications that may generate income.
Recent operational problems:	• Due to cleaning of tank, anticipated temperatures have not been reached leading to production of biogas with only 55-60% methane. • Expected biogas and electrical production has not been reached.

Project #248 (continued)	Inland Empire Utilities Agency (IEUA)

General System Overview

IEUA's Regional Plant No. 5 (RP-5) Solids Handling Facility is one of the largest centralized systems in the United States for converting manure into renewable energy. This project currently processes manure from nearby dairies in an anaerobic digester and produces biogas, which is used to generate electricity at the Chino Basin Desalter #1 facility. The Desalter is owned by the Chino Basin Desalter Authority, a joint powers of authority formed among the Jurupa Community Services District, the Santa Ana River Water Company, the cities of Chino, Chino Hills, Norco and Ontario and the Inland Empire Utilities Agency. The Desalter, located in the City of Chino, treats groundwater with high levels of salts and nitrates through reverse osmosis and ion exchange processes, and then safely introduces the highly-treated water into the potable water supply.

Also located in the City of Chino, IEUA's Regional Water Recycling Plant No. 2 (RP-2) processes biosolids from the RP-5 Wastewater Treatment Plant and the Carbon Canyon Water Recycling Facility. Solids are stabilized through anaerobic digestion, dewatered through centrifuges, and processed into compost at the Inland Empire Regional Composting Facility.

The RP-5 renewable energy digester was originally built in 2001 to digest 225 wet tons of manure a day from local dairies to generate 500 kW of electricity to power the Desalter, which creates clean drinking water for nearby communities. Phase 1 of the RP-5 renewable energy digester project was partially funded by the California Energy Commission, USDA-Natural Resources Conservation Service, and Inland Empire Utilities Agency.

In Phase 1B, partially funded through the California Energy Commission's DPPP, enhancements to the system were made to increase manure processing capacity from 225 wet tons per day to 315 wet tons per day, and to improve gas and power production. Prior to Phase 1B improvements, the system was only producing 380 kW of electricity. The Phase 1B expansion was designed to bring the system up to its 500 kW design capacity, as well as to increase total capacity by an additional 443 kW, to bring the total generating capacity to 943 kW. Phase 1B enhancements were completed in March 2006 and included the following additions to the system: bar screen to capture debris at receiving tanks; four top-mounted mixers and recirculation pump station to convert the "plug flow" digester to a "modified mix" digester; grinders; a foam suppression system, pressure/vacuum relief valves and J-tubes to improve system safety; and rotary presses to produce dryer "cake" and reduce power consumption. Also as part of the Phase 1B system improvement, but not funded by the DPPP, the digester was opened and cleaned out completely.

Six dairies provide manure for the RP-5 digester. Combined, these dairies reported populations of approximately 9,843 total cows, of which 7,931 were lactating, 1,431 were dry, and 481 were heifers. The participating dairies averaged 1,322 lactating cows, 239 dry milk cows, and 80 heifers each, for a total average of 1,641 cows per dairy. In most cases, not all the manure generated at each dairy is sent to RP-5.

At the dairies, manure is collected daily from the feed lanes using a HoneyVac vacuum tanker truck. The manure is discharged into a small holding tank on the dairy for pickup and transport to the RP-5 digester by a vacuum nurse tanker. Manure trucks are weighed at the RP-5 facility both upon arrival and once the manure is extracted from the truck. The scale is connected to an electronic control panel inside the RP-5 office facility. All incoming manure is tested for solids content and logged on a daily basis.

The RP-5 digester facility was initially designed to handle 225 wet tons of manure per day, with a total solids content of 12%, equivalent to 27 dry tons. As result of the Phase 1B modification and enhancement, the digester capacity was increased to 315 wet tons of manure per day (total solids content of 12%, equivalent to 37.8 dry tons).

The volume of manure delivered to RP-5 is currently below the expected 315 wet tons per day due to the fact that the facility is still in its startup phase. Manure delivery will be increased when the digester temperature reaches the thermophilic range.

Project #248 (continued)	Inland Empire Utilities Agency (IEUA)

General System Overview *(continued)*

At the RP-5 facility, each incoming load of manure is unloaded into a screening facility to ensure the removal of rocks and debris; it then flows into Mix Tank 1, the primary receiving pit. The collected debris is deposited onto a conveyer from which it is hauled off to landfill. The manure in the primary receiving pit is mixed and kept in constant suspension so that solids do not settle to the bottom. Here, water is added to obtain a targeted 12% solids content. The diluted manure is then transferred to Mix Tank 2, and from there it is fed into the digester. A sludge flow meter is located at each mix tank to measure flow. The RP-5 digester is a plug flow design converted to a modified-mix design, in which the digesting manure flows down one side of a divided trough and back up the other side, completing a loop. During its flow, manure is mixed by four top-mounted mixers and is recirculated back to the front of the digester after being heated by five shell and tube heat exchangers. The mixers keep sludge in suspension, thereby keeping it in contact with bacteria that break down the manure.

The digester measures approximately 195 feet long and 60 feet wide with a depth of 16 feet. The volume of the digester is about 1,100,000 gallons, or 145,800 cubic feet. The digester maintains a slurry depth of approximately 13.5 ft. Though not yet achieved, the expected feed rate is 315 wet tons per day of manure. Target solids content going into the digester is 11% to 12%. The design hydraulic retention time (HRT) in the digester ranges from 15 to 21 days. The design temperature is in the thermophilic range, with a target operating temperature of 125°F to 130°F.

Three recirculation pumps are used to pump the manure from one end of the digester, through five heat exchangers, and then back to the other end of the digester. Hot water recovered from the desalter facility cogeneration plant is used in the heat exchangers to heat the manure and thus raise the temperature of the digester. A stand-by boiler is located on site to serve as backup to the cogeneration plant.

Gas produced in the digester passes from the digester headspace to the effluent tank headspace. A foam suppression system is in place above the effluent tank ceiling to prevent foam from entering and clogging the digester gas line. The foam suppression system was one of the system improvements funded through the DPPP. Condensate from the digester gas is removed by a water trap prior entering into the gas scrubber.

A steel line carries biogas to an iron sponge. The gas scrubber is a packed bed reactor that uses iron oxide impregnated wood chips as the process media to remove hydrogen sulfide from the gas stream. The gas scrubber installed at RP-5 consists of two separate reaction chambers. The unit is designed for top-to-bottom lead-lag flow. The gas flows into the top of the first box, out the bottom of the first box, into the top of the second box, and out the bottom of the second box before leaving the system. The hydrogen sulfide levels at the outlet of the digester, the outlet of the lead iron sponge box, and the outlet of the lag iron sponge box are monitored and recorded every week to comply with the South Coast Air Quality Management District sulfur emission requirements, and in order to determine when the media should be changed in the lead box. Normal manure biogas contains 2,500-2,600 parts per million (ppm) hydrogen sulfide. The iron sponge scrubs the biogas to less than 40 ppm hydrogen sulfide levels. The spent iron sponge is landfilled off site.

After the impurities are removed, the digester gas is diverted either to an onsite gas compressor or, if needed, to a contained-flame flare. Gas is flared only when the engine-generator or compressor is down or during system maintenance. The flare is controlled by digester pressure and is automatically activated. The flare operates at lower pressure than the pressure/vacuum relief valves, which function only in the event of a flare failure or gas line blockage. An automated meter is located at the flare to measure the amount of biogas flared. Manual meter readings are taken daily to verify electronic readings.

From the scrubber, gas is conveyed to a gas tank, and from there flows to a compressor where the gas is compressed to 60 to70 psi in order to supply continuous fuel of sufficient volume to operate the engine-generators. The compressed digester gas flows to a second 30,000 gallon gas storage tank from which it flows to the Desalter facility. A biogas meter is located at this second tank to measure biogas from RP-5 going to the engine-generators at the Desalter facility located approximately one mile away.

Project #248 (continued)	Inland Empire Utilities Agency (IEUA)

General System Overview *(continued)*

The primary fuel of the two Waukesha engine-generators at the Desalter plant is the digester gas supplied from the RP-5 Solids Handling Facility and the digested gas from the RP-2 facility. If sufficient digester gas is not available, a natural gas/air blending unit at RP-2 supplies the required make-up fuel. This combination of fuel is compressed into storage vessels, metered and transported from the digesters to the Desalter engine-generators via the gas system. RP-5 and RP-2 share a common gas line to the engine-generators. If the generators are down, gas from RP-2 is diverted and is not sent to the generators. The drop in outgoing pressure at RP-2 causes a vacuum, which pulls gas from RP-5 through the common line to the RP-2 facility where it is used to fuel either a boiler and/or engine-generator for power production at that facility.

As previously mentioned, useful heat is recovered from the engine jacket water system. This coolant water is circulated through a plate and frame heat exchanger. The operating temperature range of the engine loop is 180°F to 200°F. The hot water is piped underground to the RP-5 facility to heat the digester contents.

The digester has two Pressure-Vacuum Relief Valves (PVRVs), intended to prevent damage to the digester cover due to over-pressure or over-vacuum conditions. These emergency valves automatically release when pressure reaches critical levels. Two J-tubes act as an additional emergency relief system allowing pressure to escape when needed.

The biofilter consists of wetted woody shavings used for odor removal. The air in the receiving building is ducted underground to the biofilter.

After approximately 15 to 21 days of hydraulic retention time, the digested manure slurry overflows into an effluent tank. Polymer is added to the digested sludge to aid in the dewatering process. The material is then separated into a liquid stream and a solid fraction through a rotary press. The liquid fraction is then discharged to a brine line for subsequent treatment in a wastewater treatment plant before being discharged to the ocean in accordance with permits. The dewatered “press cake” (32%-35% total solids) is loaded in to a trailer, conveyed to a composting facility and ultimately applied to land.

Each completed project is unique in a myriad of ways. Though there are similarities in some instances among the same type of systems, other aspects of the individual dairy operation or employed processes make each project a stand-alone study. The distinctive qualities of each project make side-by-side comparisons difficult to construct. The individual case studies should be referenced for a full understanding of the underlying system or dairy operation.

8. Biogas and Energy Production

Each dairy owner or project manager was faced with unique circumstances that influenced the operation and performance of their specific digester system. Table 4 below provides an estimate (when available) on the amount of biogas flared at each site. It should be noted that only one project, #248 IEUA had a flare meter installed during the study period. Two additional projects, #221 Castelanelli and #226 Van Ommering have recently installed flare meters. Recent readings confirm the estimates provided by the dairy owner during the study period are accurate.

Table 4. Capacity, Biogas Flared and Discussion

Dairy ID	Dairy Name	kW Nameplate Capacity	Actual Generation (% Capacity)	Biogas Flared? % Estimate	Discussion
Covered Lagoon Digesters					
#207	Blakes Landing	75	38%	No	Generator operates ~ 11 hrs/day
#221	Castelanelli	160	75%	Yes; 44-50%	Biogas production exceeds generator capacity. Does not use power on farm. Owner finds no economic incentive to produce additional power for net metering purposes. Excess generation credits are forfeited to the utility with no compensation.
#204	Cottonwood	300	81%	Yes; 50%	Biogas production exceeds generator capacity. In process of installing a second generator with a 400 kW capacity.
#202	Hilarides	500	77%	Yes; 20-40%	Biogas production exceeded generator capacity.
#238	Lourenco	150	0%	Yes - 100%	Engine/generator not run during study period.
Plug Flow Digesters					
#249	Eden-Vale	180	29%	Yes	Does not use power on farm. Owner finds no economic incentive to produce additional power for net metering purposes. Excess generation credits are forfeited to the utility with no compensation.
#225	Koetsier	260	24%	Yes; 15-40%	Only one of two available generators used during study period - reduced total capacity to 135 kW.
#230	Meadowbrook	160	78%	Very little	Flares only when system is down for maintenance or repair.
#226	Van Ommering	130	43%	40-50%	Inconsistent biogas production. Producing in excess of on-farm needs. No economic incentive to produce additional power for net metering purposes. In the process of connecting additional load directly to generator.
Modified Mix Plug Flow					
#248	IEUA-Phase 1B	563	0%	Yes; 26%	Flared biogas was reduced to only 6% in June 2006 as downtime was reduced substantially. Expectations are to flare only for maintenance or repair.

Digester inflow, daily biogas production and biogas production per lactating cow figures are compared in Table 5 below. Biogas production per cow averaged 44.43 cubic feet per day for the covered lagoon digesters and 48.63 cubic feet per day for the plug flow digesters.

Table 5. Digester Inflow, Biogas Production and Biogas per Cow

		# Lactating Cows	Manure Collection Method	Estimated Digester Inflow: Total (gallons per day)	Dry Total Solids (TS) (pounds per day)	Dry Volatile Soldis (VS) (pounds per day)	Average Biogas Production (cubic feet per day)	Average Biogas Production (cubic feet/day/cow)
Covered Lagoon Digesters								
#207	Blakes Landing	245	Flush	30,000	4,194	2,826	14,832	60.5
#221	Castelanelli	1,601	Flush	541,495	49,210	19,003	89,148	55.7
#204	Cottonwood	4,971	Flush	1,546,000	30,378	19,244	112,957	22.7
#202	Hilarides (heifers)	6,000	Flush	180,000	13,368	7,074	232,681	38.8
#238	Lourenco	1,258	Flush	93,000	na	na	na	na
	Average							***44.43***
Plug Flow Digesters								
#249	Eden-Vale	800	Scrape	15,000	18,843	13,427	40,360	50.5
#225	Koetsier	1,266	Scrape	30,000	20,044	15,663	44,193	34.9
#230	Meadowbrook	2,093	Scrape	20,242	17,177	13,291	80,507	38.5
#226	Van Ommering	480	Scrape	2,857	3,407	2,297	33,935	70.7
	Average							***48.63***
Modified Mix Plug Flow								
#248	IEUA-Phase 1B	7,931	Scrape at dairy; central collection	34,532	34,580	27,664	113,189	14.3

Each dairy owner or project manager was faced with unique circumstances in determining the number of hours to run the engine-generator. Most ran their systems at full possible capacity, bringing the system down only for routine maintenance or repairs. The Blakes Landing engine-generator was purposely run only half the day. Several projects flared a significant amount of the available biogas due to the lack of economic incentive to produce excess power. In any case, it is evident that significant downtime does occur thereby lowering the actual generating capacity. In the table below, nameplate capacity and total possible generating capacity (assuming the system is run 100% of the time) is compared to actual generation and percent of capacity, by digester type.

Table 6. Nameplate Capacity, Possible and Actual Generating Capacity

Dairy ID	Dairy Name	kW Nameplate Capacity	Possible Yearly Generation (kWh) *Assuming 100% capacity*	Actual Average Monthly Generation (kWh)	Actual Average Yearly Generation (kWh)	Actual Generation (% of capacity)
Covered Lagoon Digesters						
#207	Blakes Landing	75	657,000	21,066	252,792	38%
#221	Castelanelli	160	1,401,600	87,880	1,054,560	75%
#204	Cottonwood	300	2,628,000	177,757	2,133,084	81%
#202	Hilarides	500	4,380,000	280,872	3,370,460	77%
#238	Lourenco	150	1,314,000	na	na	0%
	Average		***2,076,120***		***1,702,724***	***68%***
Plug Flow Digesters						
#249	Eden-Vale	180	1,576,800	37,764	453,168	29%
#225	Koetsier	260	2,277,600	44,991	539,892	24%
#230	Meadowbrook	160	1,401,600	91,553	1,098,636	78%
#226	Van Ommering	130	1,138,800	40,529	486,348	43%
	Average		***1,598,700***		***644,511***	***43%***
Modified Mix Plug Flow						
#248	IEUA-Phase 1B	563	4,931,880	0	0	0%

Actual electrical generation and generation per cow figures are compared in Table 7 below. Electrical generation per cow varied across projects, averaging 1.84 kWh per cow per day for the covered lagoon digester projects and 1.73 kWh per cow per day for the plug flow digester projects.

Table 7. Actual Electrical Generation– Per Cow Comparisons

Dairy ID	Dairy Name	# Lactating Cows	kW Nameplate Capacity	Actual Average Yearly Generation (kWh)	Actual Average Daily Generation (kWh)	Actual Average Daily Generation (kWh per cow)
Covered Lagoon Digesters						
#207	Blakes Landing	245	75	252,792	693	2.83
#221	Castelanelli	1,601	160	1,054,560	2,889	1.80
#204	Cottonwood	4,971	300	2,133,084	5,844	1.18
#202	Hilarides	6,000	500	3,370,460	9,234	1.54
#238	Lourenco	1,390	150	na	na	na
Plug Flow Digesters						
#249	Eden-Vale	800	180	453,168	1,242	1.55
#225	Koetsier	1,266	260	539,892	1,479	1.17
#230	Meadowbrook	2,093	160	1,098,636	3,010	1.44
#226	Van Ommering	480	130	486,348	1,332	2.78
Modified Mix Plug Flow						
#248	IEUA-Phase 1B	7,931	563	0	0	na

Several factors influence the generation per cow figures, primarily the amount of biogas flared and subsequently not utilized by the engine-generator for power production. More detail is provided in Table 8 below. Again, individual case studies should be referenced for a full discussion.

On-farm electrical usage is compared to potential electrical generation and actual generation in Table 8 below. Most systems were designed to produce enough electricity to offset on farm electrical needs. In most design calculations, downtime for maintenance and repair was factored into the equation when calculating estimated generating capacity. Unfortunately, not all the projects were able to use the generated power on farm (individual discussions can be found in the case studies). Those who did not utilize the power on farm net metered all their power production. The economic incentive to net meter fell short of the dairy owner's expectations. In most cases, excess generation credits were forfeited to the utility with no compensation. Those dairy owners who used the generated power on farm did enjoy greater returns due to a reduction in electricity purchased from the utility, however due to the fact that demand charges were not subsequently reduced, their returns, once again, fell short of expectations. In almost all cases, the projects were capable of producing surplus energy and many did. Several projects, however, found no economic incentive to produce surplus electricity and therefore purposely ran their engine-generators at less than capacity. Again, individual case studies should be referenced for a full discussion.

Table 8. On-farm Usage Compared to Potential and Actual Power Generation

Dairy ID	Dairy Name	Average Electrical Usage Prior to Digester Installation (kWh/month)	Potential Generation (kWh/month) *Assuming 100% Capacity*	Potential Generation as a % of Historical Usage	Actual Average Generation (kWh/month)	Actual Generation as a % of Historical Usage
Covered Lagoon Digesters						
#207	Blakes Landing	21,597	54,750	254%	21,066	98%
#221	Castelanelli	72,313	116,800	162%	87,880	122%
#204	Cottonwood	908,200	219,000	24%	177,757	20%
#202	Hilarides	203,999	365,000	179%	280,872	138%
#238	Lourenco	45,698	109,500	240%	na	na
Plug Flow Digesters						
#249	Eden-Vale	23,314	131,400	564%	37,764	162%
#225	Koetsier	55,265	189,800	343%	44,991	81%
#230	Meadowbrook	89,316	116,800	131%	91,553	103%
#226	Van Ommering	32,260	94,900	294%	40,529	126%
Modified Mix Plug Flow						
#248	IEUA-Phase 1B	1,095,796	410,990	38%	0	0%

Six of the projects generated enough electricity to match or exceed their historical on farm usage. Several of the projects were capable of producing additional excess power if incentives existed (such as power purchase agreements).

9. System Costs

Detailed cost summaries are provided for each project at the end of this section and should be referenced for a full detail of costs for each project. For the purposes of the analysis below, any additional costs or repair and maintenance costs incurred after project completion are not included in the total cost figure. For project #230, costs incurred prior to digester construction are not included in the tables below but are noted in the individual summary of project costs. For refurbishment projects, costs incurred prior to refurbishment are included in the summary. For project #248, only those costs associated with the Phase 1B expansion are used for the analysis below.

Total costs and the cost per cow and per kW capacity are noted in Table 9 below. The total costs of ten completed projects averaged $1,065,538 for covered lagoon digesters, $930,335 for plug flow digesters and $3,551,448 for the one modified-mix plug flow digester. Cost per cow averaged $585 for covered lagoon digesters, $1,042 for plug flow digesters and $448 for the modified-mix plug flow digester. Cost per kW nameplate capacity averaged $4,654 for covered lagoon digesters, $5,159 for plug flow digesters and $6,308 for the modified-mix plug flow digester. Projects #207, #238 and #225 were refurbishments of existing non-operational digesters however, as noted, total costs including initial costs and refurbishment costs, are included in the cost figures below. Project #248 was for the expansion and modification of an existing operational system; costs included are for the expansion phase only.

Table 9. Total Project Costs and Cost per Cow and per kW

Dairy ID	Dairy Name	# Lactating Cows	kW Nameplate Capacity	Estimated Total Cost at Completion	Estimated Cost per Cow	Estimated Total Cost per kW
Covered Lagoon Digesters						
#207	Blakes Landing (initial & refurbishment costs)	245	75	$334,680	$1,366	$4,462
#221	Castelanelli	1,601	160	$882,136	$551	$5,513
#204	Cottonwood	4,971	300	$2,498,038	$503	$8,327
#202	Hilarides	6,000	500	$1,239,923	$207	$2,480
#238	Lourenco (initial & refurbishment costs)	1,258	150	$372,912	$296	$2,486
	Average			***$1,065,538***	***$585***	***$4,654***
Plug Flow Digesters						
#249	Eden-Vale	800	180	$802,811	$1,004	$4,460
#225	Koetsier (initial & refurbishment costs)	1,266	260	$1,361,087	$1,075	$5,235
#230	Meadowbrook	2,093	160	$720,605	$344	$4,504
#226	Van Ommering	480	130	$836,838	$1,743	$6,437
	Average			***$930,335***	***$1,042***	***$5,159***
Modified Mix Plug Flow						
#248	IEUA-Phase 1B (Expansion only)	7,931	563	$3,551,448	$448	$6,308

As mentioned, detailed cost summaries are provided for each project at the end of this section. The major cost categories and included line items are listed below:

Manure Collection and Pretreatment

- Lagoon constructed for biogas system
- Manure collection (piping, pumps, electrical supply, etc.)
- Vacuum trailer
- Solids separator / grit removal
- Collection mix tank

Digester and Gas Production Enhancements

- Digester / digester tank (for plug flow and modified mix digesters)
- Lagoon cover system (for covered lagoon digesters)
- Digester heating system
- Bacterial treatment

Energy Conversion and Gas Handling

- Engine-generator
- Engine-generator room or building
- Gas transport (boosters, blowers, pumps, piping, compressors, etc.)
- Flare
- Gas treatment (scrubber / cleaning system)
- Controls, panels, meters and instrumentation (biogas & electricity)
- Heat recovery

General Construction (for work not already allocated)

- Excavation, trenching, and grading (including equipment usage)
- Concrete work and materials
- Electrical work and materials
- Other contractor / subcontractor work
- Dairy labor used for construction and installation (if documented)
- Transportation, fuel, and heavy equipment rental
- Other equipment and materials

Other major cost categories include:

- System Design and Engineering
- Permits
- Utility Interconnection
- Other Associated Costs

Major cost categories as detailed in the individual cost studies are compared in Table 10 below. Not all projects reported costs for each item.

Table 10. Major Cost Categories

Dairy ID	Dairy Name	Initial Costs for Refurb. Projects	Manure Collection and Pretreatment	Digester and Gas Production Enhancements	Energy Conversion and Gas Handling	General Construction (if not already included)	System Design and Engineering	Permits	Utility Interconnect	Other Costs	Total Cost at Completion
Covered Lagoon Digesters											
#207	Blakes Landing (initial & refurb costs)	$175,000	$0	$7,605	$113,740	$0	$23,000	$0	$15,335	$0	$334,680
#221	Castelanelli		$160,276	$204,768	$205,140	$194,195	$61,595	$200	$54,391	$1,570	$882,136
#204	Cottonwood		$546,331	$341,250	$305,190	$1,039,233	$147,252	$1,080	$71,436	$46,266	$2,498,038
#202	Hilarides		$0	$366,286	$600,526	$233,226	$18,304	$240	$21,341	$0	$1,239,923
#238	Lourenco (initial & refurb costs)	$142,255	$125,222	$32,238	$39,059	$0	$12,000	$0	$22,138	$0	$372,912
	Average	***$158,628***	***$166,366***	***$190,429***	***$252,731***	***$293,331***	***$52,430***	***$304***	***$36,928***	***$9,567***	***$1,065,538***
Plug Flow Digesters											
#249	Eden-Vale		$63,500	$374,934	$185,152	$58,280	$65,385	$3,289	$52,270	$0	$802,811
#225	Koetsier (initial & refurb costs)	$998,000	$186,378	$84,853	$75,339	$0	$9,963	$140	$6,413	$0	$1,361,087
#230	Meadowbrook		$44,802	$345,359	$216,181	$34,842	$60,321	$7,846	$11,253	$0	$720,605
#226	Van Ommering		$115,615	$370,394	$196,100	$64,854	$48,440	$4,000	$37,435	$0	$836,838
	Average		***$102,574***	***$293,885***	***$168,193***	***$39,494***	***$46,028***	***$3,819***	***$26,843***	***$0***	***$930,335***
Modified Mix Plug Flow											
#248	IEUA-Phase 1B (expansion)		$1,447,125	$1,449,938	$92,594	$374,318	$127,763	$1,426	$2,493	$55,791	**$3,551,448**

For the covered lagoon digesters, on average, energy conversion, gas handling and general construction were the largest cost categories, comprising 24% and 28% respectively of the total average costs. For the plug flow digesters, on average, digester and gas production enhancements was the largest cost category, comprising 32% of the total average costs. For the modified mix plug flow system, digester and gas production enhancement was the largest category, comprising nearly 41% of the total costs.

Pie charts highlighting the major cost categories are shown for each project below, grouped by digester type. A general legend is shown on each page.

Figure 4. Covered Lagoon Major Cost Categories

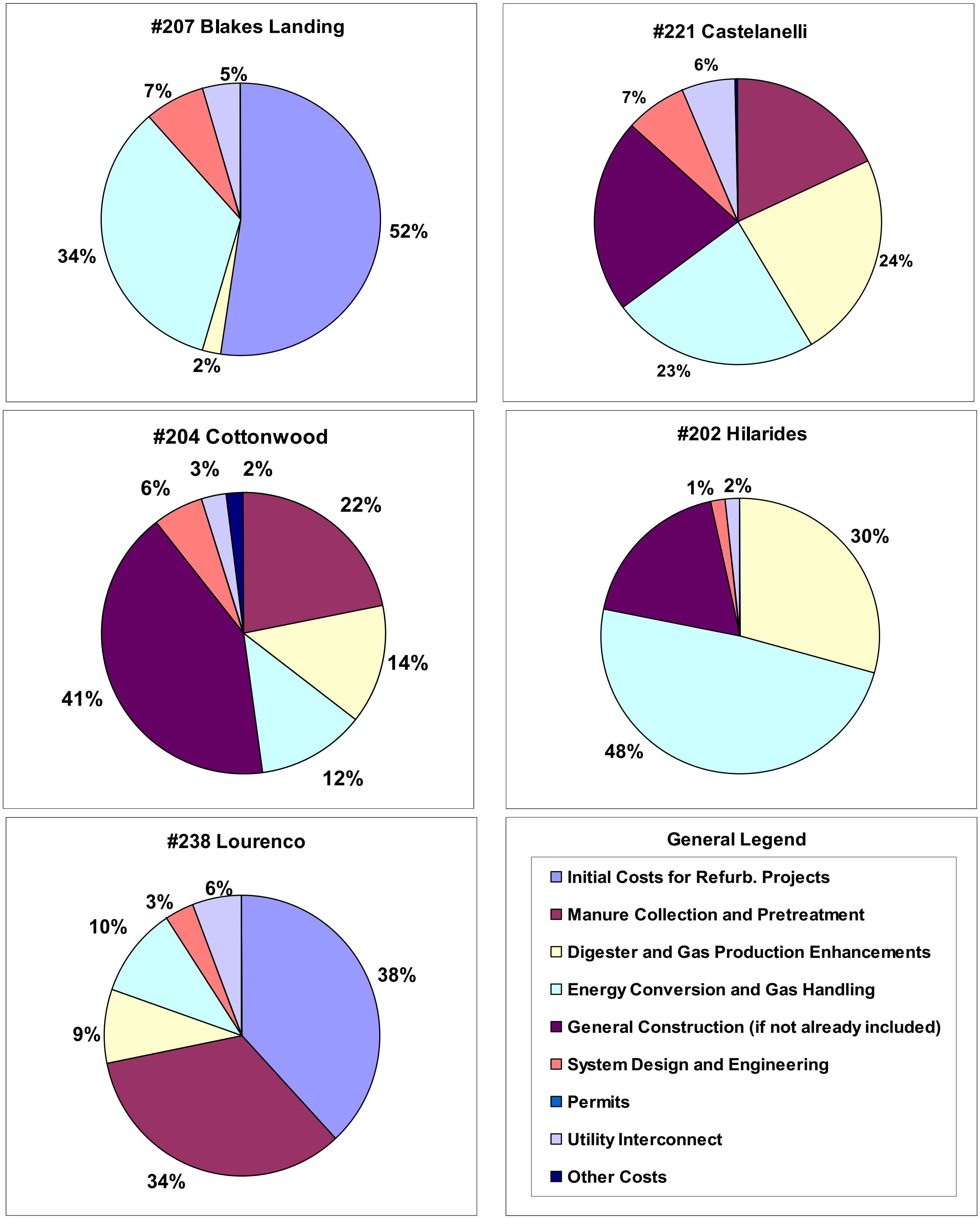
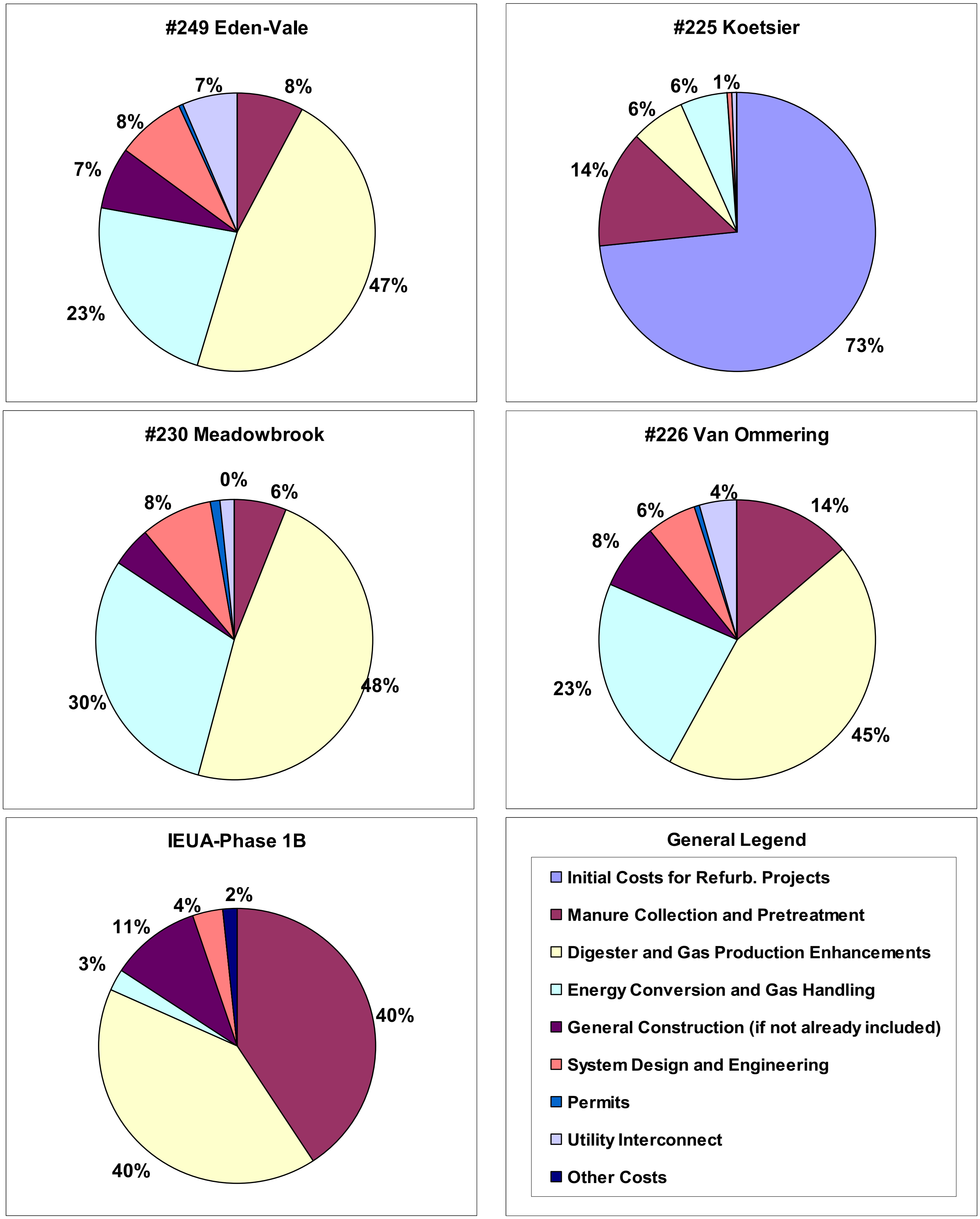


Figure 5. Plug Flow and Modified Mix Plug Flow Major Cost Categories



Summary of Costs, Project #207, Blakes Landing Farms

Section A. Project Information	
1. Dairy name	**#207-B, Blakes Landing Farms**
2. Purpose of grant	To refurbish an existing, non-operational covered lagoon digester system
3. Total generator nameplate capacity	**75 kW**

Section B. Manure Collection and Pretreatment	**Estimated Costs**	**Actual Construction (Labor) Costs**	**Actual Equipment and Materials Costs**	**Equip/Mat'ls, LABOR INCLUDED**	**Total Actual Costs**
1. Lagoon constructed for biogas system					0.00
2. Lagoon liner					0.00
3. Manure collection (piping, pumps, electrical supply, etc.)					0.00
4. Vacuum trailer					0.00
5. Solids separator / grit removal					0.00
6. Collection mix tank					0.00
Subtotal	***0.00***	***0.00***	***0.00***	***0.00***	***0.00***
Section C. Digester and Gas Production Enhancements					
1. Digester / digester tank					0.00
2. Lagoon cover system *(installed prior to this grant, see Section K below)*					0.00
3. Digester heating system				7,605.00	7,605.00
4. Bacterial treatment					0.00
Subtotal	***0.00***	***0.00***	***0.00***	***7,605.00***	***7,605.00***
Section D. Energy Conversion and Gas Handling					
1. Engine / generator *(a rebuilt genset was purchased)*	55,000.00				
(a) One (1) Waukesha 817G engine-generator, 75 kW capacity			54,553.92		54,553.92
(b) Engine / generator additional components, overhaul, or repair		2,898.50	1,210.56		4,109.06
2. Engine / generator room or building	15,000.00		1,496.49		1,496.49
3. Gas transport (boosters, blowers, pumps, piping, compressors, etc.)	8,500.00	2,520.00	14,010.10		16,530.10
4. Flare		1,219.00	20.76		1,239.76
5. Gas treatment (scrubber / cleaning system)					0.00
6. Controls, panels, meters and instrumentation (biogas & electricity)	11,500.00	370.00	92.06	16,760.00	17,222.06
7. Heat recovery (hot water; specify if other)	10,000.00		7,088.78	11,500.00	18,588.78
Subtotal	***100,000.00***	***7,007.50***	***78,472.67***	***28,260.00***	***113,740.17***
Section E. General Construction (for work not allocated to Sections B-D above)					
1. Excavation, trenching, and grading (including equipment usage)					0.00
2. Concrete work and materials					0.00
3. Electrical work and materials					0.00
4. Other contractor / subcontractor work (not already allocated)					0.00
5. Dairy labor used for construction and installation (if documented)					0.00
6. Transportation, fuel, and heavy equipment rental					0.00
7. Other equipment and materials (describe):					0.00
Subtotal	***0.00***	***0.00***	***0.00***	***0.00***	***0.00***
Section F. System Design and Engineering					
1. Overall system design / engineering	25,000.00	23,000.00			23,000.00
Subtotal	***25,000.00***	***23,000.00***	***0.00***	***0.00***	***23,000.00***
Section G. Permits					
1. Permits - air					0.00
2. Permits - building					0.00
Subtotal	***0.00***	***0.00***	***0.00***	***0.00***	***0.00***
Section H. Utility Interconnection					
1. Interconnection permit and inspection process	800.00	800.00			800.00
2. Interconnection equipment required by utility (switch gear/relays, safety)	10,000.00		2,602.96	11,932.00	14,534.96
Subtotal	***10,800.00***	***800.00***	***2,602.96***	***11,932.00***	***15,334.96***
Section I. Other Associated Costs					
1. Overhead / administrative costs (describe):					0.00
2. Finance charge / capitalized interest (explain):					0.00
Subtotal	***0.00***	***0.00***	***0.00***	***0.00***	***0.00***
Section J. Total Costs Reported for this Grant					
TOTAL	**135,800.00**	**30,807.50**	**81,075.63**	**47,797.00**	**159,680.13**

Section K. Comprehensive System Costs to Date	
1. Initial costs incurred prior to refurbishment *(originally done in 2000) - Converted lagoon to anaerobic digester* *-Including installation of a floating cover (approximately 12,000 ft^2, 60 mil reinforced PPE @ approximately 1.67/ft^2)*	**175,000.00**
2. Costs incurred after system completion (not included above) *-Added a computerized engine output controller and a computer to monitor generator electricity output*	**3,100.00**
TOTAL SYSTEM COSTS TO DATE	**337,780.13**

Summary of Costs, Project #221, Castelanelli Bros.

Section A. Project Information					
1. Dairy name	**#221-B, Castelanelli Bros.**				
2. Purpose of grant	To install a new covered lagoon digester system				
3. Total generator nameplate capacity	**160 kW**				
Section B. Manure Collection and Pretreatment	**Estimated Costs**	**Actual Construction (Labor) Costs**	**Actual Equipment and Materials Costs**	**Equip/Mat'ls, LABOR INCLUDED**	**Total Actual Costs**
1. Lagoon constructed for biogas system	178,556.00	55,734.00			55,734.00
2. Lagoon liner					0.00
3. Manure collection (piping, pumps, electrical supply, etc.)	6,820.00	7,818.81	33,205.53		41,024.34
4. Vacuum trailer					0.00
5. Solids separator / grit removal		5,851.50	57,666.26		63,517.76
6. Collection mix tank					0.00
Subtotal	***185,376.00***	***69,404.31***	***90,871.79***	***0.00***	***160,276.10***
Section C. Digester and Gas Production Enhancements					
1. Digester / digester tank					0.00
2. Lagoon cover system. **Total area covered: 111,414 ft^2**	265,974.00		204,768.00		204,768.00
(a) Lagoon cover(s):					
-One (1) floating cover, 186' x 599' (80 mil HDPE)					
(b) Lagoon cover additional components					0.00
3. Digester heating system					0.00
4. Bacterial treatment					0.00
Subtotal	***265,974.00***	***0.00***	***204,768.00***	***0.00***	***204,768.00***
Section D. Energy Conversion and Gas Handling					
1. Engine / generator *(purchased new)*	223,373.00				0.00
(a) One (1) CAT G3406T engine-generator, 160 kW capacity			124,460.00		124,460.00
(b) Engine / generator additional components, overhaul, or repair		292.50	8,981.51		9,274.01
2. Engine / generator room or building		550.00	14,176.24	8,941.80	23,668.04
3. Gas transport (boosters, blowers, pumps, piping, compressors, etc.)	21,413.00	75.43	37,448.35		37,523.78
4. Flare *(flare was constructed, not purchased)*			1,799.42		1,799.42
5. Gas treatment (scrubber / cleaning system)					0.00
6. Controls, panels, meters and instrumentation (biogas & electricity)	1,978.00		8,415.23		8,415.23
7. Heat recovery (hot water; specify if other)					0.00
Subtotal	***246,764.00***	***917.93***	***195,280.75***	***8,941.80***	***205,140.48***
Section E. General Construction (not allocated in Sections B-D above)					
1. Excavation, trenching, and grading (including equipment usage)					0.00
2. Concrete work and materials					0.00
3. Electrical work and materials		8,696.58	14,513.44		23,210.02
Electrical engineering, parts, wiring, and labor					
4. Other contractor / subcontractor work (not already allocated)					0.00
5. Dairy labor used for construction and installation (if documented)		156,568.00			156,568.00
6. Transportation, fuel, and heavy equipment rental					0.00
7. Other equipment and materials: *RCM Digesters, categories not specified*			14,416.67		14,416.67
Subtotal	***0.00***	***165,264.58***	***28,930.11***	***0.00***	***194,194.69***
Section F. System Design and Engineering					
1. Overall system design / engineering	69,811.00	61,594.88			61,594.88
Subtotal	***69,811.00***	***61,594.88***	***0.00***	***0.00***	***61,594.88***
Section G. Permits					
1. Permits - air					0.00
2. Permits - building *(total reported is estimated)*				200.00	200.00
Subtotal	***0.00***	***0.00***	***0.00***	***200.00***	***200.00***
Section H. Utility Interconnection					
1. Interconnection permit and inspection process		46,524.24			46,524.24
2. Interconnection equipment required by utility (switch gear/relays, safety)		2,636.75		5,230.00	7,866.75
Subtotal	***0.00***	***49,160.99***	***0.00***	***5,230.00***	***54,390.99***
Section I. Other Associated Costs					
1. Overhead/admin costs: *RCM Digesters tax/freight (categories not specified)*	5,000.00			1,570.48	1,570.48
2. Finance charge / capitalized interest (explain):					0.00
Subtotal	***5,000.00***	***0.00***	***0.00***	***1,570.48***	***1,570.48***
Section J. Total Costs Reported for this Grant					
TOTAL	**772,925.00**	**346,342.69**	**519,850.65**	**15,942.28**	**882,135.62**

Section K. Comprehensive System Costs to Date	
1. Initial costs incurred prior to this grant	
2. Costs incurred after system completion (not included above)	**84,727.22**
-Rewired to connect milk barn, 3 lagoon pumps, well, and separator to engine-generator	
TOTAL SYSTEM COSTS TO DATE	**966,862.84**

Summary of Costs, Project #204, Cottonwood Dairy

Section A. Project Information					
1. Dairy name	**#204-B, Cottonwood Dairy**				
2. Purpose of grant	To install a new covered lagoon digester system				
3. Total generator nameplate capacity	**300 kW**				
Section B. Manure Collection and Pretreatment	**Estimated Costs**	**Actual Construction (Labor) Costs**	**Actual Equipment and Materials Costs**	**Equip/Mat'ls, LABOR INCLUDED**	**Total Actual Costs**
1. Lagoon constructed for biogas system	135,572.00	177,666.44	171,992.70		349,659.14
2. Lagoon liner					0.00
3. Manure collection (piping, pumps, electrical supply, etc.)	50,000.00		19,226.75		19,226.75
4. Vacuum trailer					0.00
5. Solids separator / grit removal		7,311.26		170,133.96	177,445.22
6. Collection mix tank	194,148.00				0.00
Subtotal	***379,720.00***	***184,977.70***	***191,219.45***	***170,133.96***	***546,331.11***
Section C. Digester and Gas Production Enhancements					
1. Digester / digester tank					0.00
2. Lagoon cover system. **Total area covered: 323,871 ft^2**	242,000.00		341,250.00		341,250.00
(a) Lagoon cover(s):					
-One (1) floating cover, 1213' x 267' (60 mil HDPE)					
-Note: total area of cover material purchased: 329,400 ft^2					
(b) Lagoon cover additional components					0.00
3. Digester heating system					0.00
4. Bacterial treatment					0.00
Subtotal	***242,000.00***	***0.00***	***341,250.00***	***0.00***	***341,250.00***
Section D. Energy Conversion and Gas Handling					
1. Engine / generator *(purchased new)*	467,000.00		90,114.40		90,114.40
(a) One (1) CAT G3412 TS engine-generators, 300 capacity					0.00
(b) Engine / generator additional components, overhaul, or repair		1,504.27	2,030.81		3,535.08
2. Engine / generator room or building	37,500.00				0.00
3. Gas transport (boosters, blowers, pumps, piping, compressors, etc.)	37,500.00		525.46	211,015.00	211,540.46
4. Flare *(included in Line D3)*					0.00
5. Gas treatment *(scrubber included in Line D3)*					0.00
6. Controls, panels, meters and instrumentation (biogas & electricity)					0.00
7. Heat recovery (hot water; specify if other)					0.00
Subtotal	***542,000.00***	***1,504.27***	***92,670.67***	***211,015.00***	***305,189.94***
Section E. General Construction (not allocated in Sections B-D above)					
1. Excavation, trenching, and grading (including equipment usage)					0.00
2. Concrete work and materials			39,307.86	52,422.60	91,730.46
3. Electrical work and materials				33,977.50	33,977.50
4. Other contractor / subcontractor work (not already allocated)		58,620.04		258,054.24	316,674.28
5. Dairy labor used for construction and installation (if documented)		180,236.64			180,236.64
6. Transportation, fuel, and heavy equipment rental		176,166.55			176,166.55
7. Other equipment and materials (describe):		16,349.86	224,097.35		240,447.21
Subtotal	***0.00***	***431,373.09***	***263,405.21***	***344,454.34***	***1,039,232.64***
Section F. System Design and Engineering					
1. Overall system design / engineering	75,000.00	147,251.92			147,251.92
Subtotal	***75,000.00***	***147,251.92***	***0.00***	***0.00***	***147,251.92***
Section G. Permits					
1. Permits - air	800.00			1,080.00	1,080.00
2. *Permit for lagoon construction obtained from Merced County*					0.00
Environmental Health Department. There is no fee for this permit.					
Subtotal	***800.00***	***0.00***	***0.00***	***1,080.00***	***1,080.00***
Section H. Utility Interconnection					
1. Interconnection permit and inspection process		10,135.15		600.00	10,735.15
2. Interconnection equipment required by utility (switch gear/relays, safety)	50,000.00	3,600.00		57,100.77	60,700.77
Subtotal	***50,000.00***	***13,735.15***	***0.00***	***57,700.77***	***71,435.92***
Section I. Other Associated Costs					
1. Overhead / administrative costs (describe):					0.00
2. Finance charge / capitalized interest (explain):		1,936.03		44,330.24	46,266.27
Subtotal	***0.00***	***1,936.03***	***0.00***	***44,330.24***	***46,266.27***
Section J. Total Costs Reported for this Grant					
TOTAL	**1,289,520.00**	**780,778.16**	**888,545.33**	**828,714.31**	**2,498,037.80**

Section K. Comprehensive System Costs to Date	
1. Initial costs incurred prior to this grant	**0.00**
2. Costs incurred after system completion (not included above) total is estimated	**200,000.00**
-Replaced H_2S scrubber (approx $10K); gas supply improvements, and electrical work	
TOTAL SYSTEM COSTS TO DATE	**2,698,037.80**

Summary of Costs, Project #202, Hilarides Dairy

Section A. Project Information					
1. Dairy name	**Hilarides Dairy**				
2. Purpose of grant	To install a new covered lagoon digester system				
3. Total generator nameplate capacity	**500 kW**				

Section B. Manure Collection and Pretreatment	Estimated Costs	Actual Construction (Labor) Costs	Actual Equipment and Materials Costs	Equip/Mat'ls, LABOR INCLUDED	Total Actual Costs
1. Lagoon constructed for biogas system					0.00
2. Lagoon liner					0.00
3. Manure collection (piping, pumps, electrical supply, etc.)					0.00
4. Vacuum trailer					0.00
5. Solids separator / grit removal					0.00
6. Collection mix tank					0.00
Subtotal	***0.00***	***0.00***	***0.00***	***0.00***	***0.00***
Section C. Digester and Gas Production Enhancements					
1. Digester / digester tank					0.00
2. Lagoon cover system. **Total area covered: 288,500 square feet.**	750,000.00				
(a) Lagoon cover(s):		186,406.10	163,832.94		350,239.04
-One (1) bank-to-bank cover, 1,100' x 220' (60 mil HDPE)					
-Five (5) floating covers totaling 300' x 155' (45 mil PPL)					
(b) Lagoon cover additional components		11,400.00	4,647.13		16,047.13
3. Digester heating system					0.00
4. Bacterial treatment					0.00
Subtotal	***750,000.00***	***197,806.10***	***168,480.07***	***0.00***	***366,286.17***
Section D. Energy Conversion and Gas Handling					
1. Engine / generator *(all gensets were purchased used & then refurbished)*	300,000.00				
(a) Four (4) CAT G342 engine-generators, 125 kW capacity each			20,000.00		20,000.00
(b) Engine / generator additional components, overhaul, or repair		10,205.00	144,183.48	4,225.00	158,613.48
2. Engine / generator room or building		2,405.00	4,300.70	2,341.00	9,046.70
3. Gas transport (boosters, blowers, pumps, piping, compressors, etc.)	50,000.00	30,361.04	31,298.37	5,000.00	66,659.41
4. Flare *(flare was constructed, not purchased; cost rolled into Line D3)*					0.00
5. Gas treatment (scrubber / cleaning system)					0.00
6. Controls, panels, meters and instrumentation (biogas & electricity)	230,000.00	1,200.00	158,825.28	186,181.60	346,206.88
7. Heat recovery (hot water; specify if other)					0.00
Subtotal	***580,000.00***	***44,171.04***	***358,607.83***	***197,747.60***	***600,526.47***
Section E. General Construction (for work not allocated to Sections B-D above)					
1. Excavation, trenching, and grading (including equipment usage)					0.00
2. Concrete work and materials					0.00
3. Electrical work and materials *(To connect generator to barn, wells, etc.)*				233,225.60	233,225.60
4. Other contractor / subcontractor work (not already allocated)					0.00
5. Dairy labor used for construction and installation (if documented)					0.00
6. Transportation, fuel, and heavy equipment rental					0.00
7. Other equipment and materials (describe):					0.00
Subtotal	***0.00***	***0.00***	***0.00***	***233,225.60***	***233,225.60***
Section F. System Design and Engineering					
1. Overall system design / engineering	50,000.00	18,123.88	180.60		18,304.48
Subtotal	***50,000.00***	***18,123.88***	***180.60***	***0.00***	***18,304.48***
Section G. Permits					
1. Permits - air *($60 annual add-on fee for each engine)*				240.00	240.00
2. Permits - building *(rolled into contractor fees, included in Line D2)*					0.00
Subtotal	***0.00***	***0.00***	***0.00***	***240.00***	***240.00***
Section H. Utility Interconnection					
1. Interconnection permit and inspection process		1,319.00			1,319.00
2. Interconnection equipment required by utility (switch gear/relays, safety)	100,000.00		4,640.00	15,381.75	20,021.75
Subtotal	***100,000.00***	***1,319.00***	***4,640.00***	***15,381.75***	***21,340.75***
Section I. Other Associated Costs					
1. Overhead / administrative costs (describe):					0.00
2. Finance charge / capitalized interest (explain):					0.00
Subtotal	***0.00***	***0.00***	***0.00***	***0.00***	***0.00***
Section J. Total Costs Reported for this Grant					
TOTAL	**1,480,000.00**	**261,420.02**	**531,908.50**	**446,594.95**	**1,239,923.47**

Section K. Comprehensive System Costs to Date	
1. Initial costs incurred prior to this grant	**0.00**
2. Costs incurred after system completion (not included above)	**0.00**
TOTAL SYSTEM COSTS TO DATE	**1,239,923.47**

Summary of Costs, Project #238, Lourenco Dairy

Section A. Project Information	
1. Dairy name	**#238-B, Lourenco Dairy**
2. Purpose of grant	To refurbish an existing, non-operational covered lagoon digester system
3. Total generator nameplate capacity	**150 kW**

Section B. Manure Collection and Pretreatment	Estimated Costs	Actual Construction (Labor) Costs	Actual Equipment and Materials Costs	Equip/Mat'ls, LABOR INCLUDED	Total Actual Costs
1. Lagoon constructed for biogas system					0.00
2. Lagoon liner					0.00
3. Manure collection (piping, pumps, electrical supply, etc.)	15,130.00	549.02	8,845.98		9,395.00
4. Vacuum trailer					0.00
5. Solids separator / grit removal	50,177.00	11,761.54	53,545.24	50,520.00	115,826.78
6. Collection mix tank					0.00
Subtotal	***65,307.00***	***12,310.56***	***62,391.22***	***50,520.00***	***125,221.78***
Section C. Digester and Gas Production Enhancements					
1. Digester / digester tank					0.00
2. Lagoon cover system. **Total area covered: 28,033 ft^2 @ $1.15/sq ft**	40,500.00			**32,237.95**	32,237.95
(a) Lagoon cover(s):					
-One (1) floating cover, 289' x 97' (60 mil HDPE)					
(b) Lagoon cover additional components *(included in cover price above)*					0.00
3. Digester heating system					0.00
4. Bacterial treatment					0.00
Subtotal	***40,500.00***	***0.00***	***0.00***	***32,237.95***	***32,237.95***
Section D. Energy Conversion and Gas Handling					
1. Engine / generator *(genset was purchased used and refurbished prior to grant)*					0.00
(a) One (1) CAT 353 engine-generator, 150 kW capacity					0.00
(b) Engine / generator additional components, overhaul, or repair		1,446.00	2,689.06		4,135.06
2. Engine / generator room or building					0.00
3. Gas transport (boosters, blowers, pumps, piping, compressors, etc.)		488.84	1,624.84		2,113.68
4. Flare *(purchased used flare; only had to plumb it in)*				250.00	250.00
5. Gas treatment (scrubber / cleaning system)		2,770.07	9,116.25		11,886.32
6. Controls, panels, meters and instrumentation (biogas & electricity)	12,862.00	3,600.00	17,073.93		20,673.93
7. Heat recovery (hot water; specify if other)	13,500.00				0.00
Subtotal	***26,362.00***	***8,304.91***	***30,504.08***	***250.00***	***39,058.99***
Section E. General Construction (for work not allocated to Sections B-D above)					
1. Excavation, trenching, and grading (including equipment usage)					0.00
2. Concrete work and materials *(for separator reception pit - included in B5)*	50,000.00				0.00
3. Electrical work and materials					0.00
4. Other contractor / subcontractor work (not already allocated)					0.00
5. Dairy labor used for construction and installation (if documented)					0.00
6. Transportation, fuel, and heavy equipment rental					0.00
7. Other equipment and materials (describe):					0.00
Subtotal	***50,000.00***	***0.00***	***0.00***	***0.00***	***0.00***
Section F. System Design and Engineering					
1. Overall system design / engineering	25,250.00	12,000.00			12,000.00
Subtotal	***25,250.00***	***12,000.00***	***0.00***	***0.00***	***12,000.00***
Section G. Permits					
1. Permits - air					0.00
2. Permits - building *(rolled into general plan for the dairy, no cost for digester)*					0.00
Subtotal	***0.00***	***0.00***	***0.00***	***0.00***	***0.00***
Section H. Utility Interconnection					
1. Interconnection permit and inspection process					0.00
2. Interconnection equipment required by utility (switch gear/relays, safety)	22,138.00	2,800.00	19,338.00		22,138.00
Subtotal	***22,138.00***	***2,800.00***	***19,338.00***	***0.00***	***22,138.00***
Section I. Other Associated Costs					
1. Overhead / administrative costs (describe):					0.00
2. Finance charge / capitalized interest (explain):					0.00
Subtotal	***0.00***	***0.00***	***0.00***	***0.00***	***0.00***
Section J. Total Costs Reported for this Grant					
TOTAL	**229,557.00**	**35,415.47**	**112,233.30**	**83,007.95**	**230,656.72**

Section K. Comprehensive System Costs to Date	
1. Initial costs incurred prior to refurbishment: *-Design/consulting; pump; 6 floating covers (41,220 ft^2, 45 mil PPE @ 1.80/ft^2);* *-Engine-generator (purchased used, then overhauled); gas lines; and miscellaneous parts*	**142,255.40**
2. Costs incurred after system completion (not included above)	**0.00**
TOTAL SYSTEM COSTS TO DATE	**372,912.12**

Summary of Costs, Project #249, Eden-Vale Dairy

Section A. Project Information					
1. Dairy name	**Eden-Vale Dairy**				
2. Purpose of grant	To install a new plug flow digester system				
3. Total generator nameplate capacity	**180 kW**				
Section B. Manure Collection and Pretreatment	**Estimated Costs**	**Actual Construction (Labor) Costs**	**Actual Equipment and Materials Costs**	**Equip/Mat'ls, LABOR INCLUDED**	**Total Actual Costs**
1. Lagoon constructed for biogas system					0.00
2. Lagoon liner					0.00
3. Manure collection (piping, pumps, electrical supply, etc.)	19,250.00				0.00
4. Vacuum trailer					0.00
5. Solids separator / grit removal	77,000.00			63,500.00	63,500.00
6. Collection mix tank	30,325.00				0.00
Subtotal	***126,575.00***	***0.00***	***0.00***	***63,500.00***	***63,500.00***
Section C. Digester and Gas Production Enhancements					
1. Digester / digester tank. **Plug flow digester volume: 59,904 ft^3 Dimensions: 30' wide x 150' long x 14' deep**	216,566.00	195,661.99	115,551.89		311,213.88
2. Lagoon cover system					0.00
3. Digester heating system		24,960.00	38,760.00		63,720.00
4. Bacterial treatment					0.00
Subtotal	***216,566.00***	***220,621.99***	***154,311.89***	***0.00***	***374,933.88***
Section D. Energy Conversion and Gas Handling					
1. Engine / generator *(engine-generator was purchased new)*	71,280.00		104,196.00		104,196.00
(a) One (1) CAT 3406 engine-generator, 180 kW capacity					0.00
(b) Engine / generator additional components, overhaul, or repair			6,700.00		6,700.00
2. Engine / generator room or building		6,500.00	21,016.32		27,516.32
3. Gas transport (boosters, blowers, pumps, piping, compressors, etc.)	76,772.00		46,740.00		46,740.00
4. Flare *(cost included in Line D3)*					0.00
5. Gas treatment (scrubber / cleaning system)	8,910.00				0.00
6. Controls, panels, meters and instrumentation (biogas & electricity)	11,220.00				0.00
7. Heat recovery (hot water; specify if other)	53,460.00				0.00
Subtotal	***221,642.00***	***6,500.00***	***178,652.32***	***0.00***	***185,152.32***
Section E. General Construction (for work not allocated to Sections B-D above)					
1. Excavation, trenching, and grading (including equipment usage)		156.00			156.00
2. Concrete work and materials					0.00
3. Electrical work and materials					0.00
4. Other contractor / subcontractor work (not already allocated)		24,927.00	30,677.41		55,604.41
5. Dairy labor used for construction and installation (if documented)					0.00
6. Transportation, fuel, and heavy equipment rental		2,520.00			2,520.00
7. Other equipment and materials (describe):					0.00
Subtotal	***0.00***	***27,603.00***	***30,677.41***	***0.00***	***58,280.41***
Section F. System Design and Engineering					
1. Overall system design / engineering	54,000.00	65,385.47			65,385.47
Subtotal	***54,000.00***	***65,385.47***	***0.00***	***0.00***	***65,385.47***
Section G. Permits					
1. Permits - air					0.00
2. Permits - building				3,288.50	3,288.50
Subtotal	***0.00***	***0.00***	***0.00***	***3,288.50***	***3,288.50***
Section H. Utility Interconnection					
1. Interconnection permit and inspection process		**43,534.95**			43,534.95
2. Interconnection equipment required by utility (switch gear/relays, safety)	35,640.00	**4,970.00**	**3,765.00**		8,735.00
Subtotal	***35,640.00***	***48,504.95***	***3,765.00***	***0.00***	***52,269.95***
Section I. Other Associated Costs					
1. Overhead / administrative costs (describe):					0.00
2. Finance charge / capitalized interest (explain):					0.00
Subtotal	***0.00***	***0.00***	***0.00***	***0.00***	***0.00***
Section J. Total Costs Reported for this Grant					
TOTAL	**654,423.00**	**368,615.41**	**367,406.62**	**66,788.50**	**802,810.53**
Section K. Comprehensive System Costs to Date					
1. Initial costs incurred prior to this grant					**0.00**
2. Costs incurred after system completion (not included above)					**0.00**
TOTAL SYSTEM COSTS TO DATE					**802,810.53**

Summary of Costs, Project #225, Koetsier Dairy

Section A. Project Information	
1. Dairy name	**#225-I, Koetsier Dairy**
2. Purpose of grant	To refurbish an existing, non-operational plug flow digester system
3. Total generator nameplate capacity	**260 kW**

Section B. Manure Collection and Pretreatment	Estimated Costs	Actual Construction (Labor) Costs	Actual Equipment and Materials Costs	Equip/Mat'ls, LABOR INCLUDED	Total Actual Costs
1. Lagoon constructed for biogas system					0.00
2. Lagoon liner					0.00
3. Manure collection (piping, pumps, electrical supply, etc.)	139,750.00	1,969.39	3,652.68		5,622.07
4. Vacuum trailer *(3750 gallon capacity Loewen 3750, purchased new)*			117,587.50		117,587.50
5. Solids separator / grit removal	47,500.00	1,799.00	61,369.47		63,168.47
6. Collection mix tank					0.00
Subtotal	***187,250.00***	***3,768.39***	***182,609.65***	***0.00***	***186,378.04***
Section C. Digester and Gas Production Enhancements					
1. Digester / digester tank. **Plug flow digester volume: approx 70,000 ft3** Dimensions: 30' wide x 180' long x 16' deep at center, 12' deep at sides	85,600.00	4,745.30	12,677.27	67,430.20	84,852.77
2. Lagoon cover system					0.00
3. Digester heating system					0.00
4. Bacterial treatment					0.00
Subtotal	***85,600.00***	***4,745.30***	***12,677.27***	***67,430.20***	***84,852.77***
Section D. Energy Conversion and Gas Handling					
1. Engine / generator *(Both gensets were refurbished through this grant)*	82,000.00				0.00
(a) One (1) used CAT G342 engine-generator, 135 kW capacity, purchased One (1) existing CAT G342 engine-generator, 135 kW capacity			10,000.00		10,000.00
(b) Engine / generator additional components, overhaul, or repair		370.00	22,399.01		22,769.01
2. Engine / generator room or building				14,576.00	14,576.00
3. Gas transport (boosters, blowers, pumps, piping, compressors, etc.)	2,000.00	10,712.50	2,537.40		13,249.90
4. Flare		2,750.00			2,750.00
5. Gas treatment (scrubber / cleaning system)					0.00
6. Controls, panels, meters and instrumentation (biogas & electricity)		4,632.26	7,362.26		11,994.52
7. Heat recovery (hot water; specify if other)					0.00
Subtotal	***84,000.00***	***18,464.76***	***42,298.67***	***14,576.00***	***75,339.43***
Section E. General Construction (for work not allocated to Sections B-D above)					
1. Excavation, trenching, and grading (including equipment usage)					0.00
2. Concrete work and materials					0.00
3. Electrical work and materials					0.00
4. Other contractor / subcontractor work (not already allocated)					0.00
5. Dairy labor used for construction and installation (if documented)					0.00
6. Transportation, fuel, and heavy equipment rental					0.00
7. Other equipment and materials (describe):					0.00
Subtotal	***0.00***	***0.00***	***0.00***	***0.00***	***0.00***
Section F. System Design and Engineering					
1. Overall system design / engineering		9,963.41			9,963.41
Subtotal	***0.00***	***9,963.41***	***0.00***	***0.00***	***9,963.41***
Section G. Permits					
1. Permits - air *($60 annual add-on fee for each engine)*	5,000.00			120.00	120.00
2. Permits - building *(county permit for electrical modifications)*				19.95	19.95
Subtotal	***5,000.00***	***0.00***	***0.00***	***139.95***	***139.95***
Section H. Utility Interconnection					
1. Interconnection permit and inspection process		1,285.25			1,285.25
2. Interconnection equipment required by utility (switch gear/relays, safety)	19,500.00	2,792.50	2,335.27		5,127.77
Subtotal	***19,500.00***	***4,077.75***	***2,335.27***	***0.00***	***6,413.02***
Section I. Other Associated Costs					
1. Overhead / administrative costs:	500.00				0.00
2. Finance charge / capitalized interest (explain):					0.00
Subtotal	***500.00***	***0.00***	***0.00***	***0.00***	***0.00***
Section J. Total Costs Reported for this Grant					
TOTAL	381,850.00	41,019.61	239,920.86	82,146.15	363,086.62

Section K. Comprehensive System Costs to Date	
1. Initial costs incurred prior to refurbishment: *-Original digester installed in 1985 as turn-key system, including: -digester tank; all electrical; -all interconnection equipment; pumps; separators; 2 generators (which had to be replaced); mixing pit; concrete; water storage tank, etc.*	**998,000.00**
2. Costs incurred after system completion (not included above) *-Remodeling of the input system*	**7,500.00**
TOTAL SYSTEM COSTS TO DATE	**1,368,586.62**

Summary of Costs, Project #230, Meadowbrook Dairy

Section A. Project Information	
1. Dairy name	**#230-B, Meadowbrook Dairy**
2. Purpose of grant	To install a new plug flow digester system
3. Total generator nameplate capacity	**160 kW**

Section B. Manure Collection and Pretreatment	Estimated Costs	Actual Construction (Labor) Costs	Actual Equipment and Materials Costs	Equip/Mat'ls, LABOR INCLUDED	Total Actual Costs
1. Lagoon constructed for biogas system					0.00
2. Lagoon liner					0.00
3. Manure collection (piping, pumps, electrical supply, etc.)	23,100.00				0.00
4. Vacuum trailer					0.00
5. Solids separator / grit removal	44,000.00		36,807.02		36,807.02
6. Collection mix tank	27,116.00		7,995.05		7,995.05
Subtotal	***94,216.00***	***0.00***	***44,802.07***	***0.00***	***44,802.07***
Section C. Digester and Gas Production Enhancements					
1. Digester / digester tank. **Plug flow digester volume: 53,312 ft^3** **Dimensions: 32' wide x 156' long x 14' deep at center**	142,076.00	76,425.75	214,446.78		290,872.53
2. Lagoon cover system					0.00
3. Digester heating system			35,326.40		35,326.40
4. Bacterial treatment			19,160.46		19,160.46
Subtotal	***142,076.00***	***76,425.75***	***268,933.64***	***0.00***	***345,359.39***
Section D. Energy Conversion and Gas Handling					
1. Engine / generator *(genset was purchased new)*	218,730.00				0.00
(a) One (1) CAT 3406TA engine-generators, 160 kW capacity			135,562.00		135,562.00
(b) Engine / generator additional components, overhaul, or repair			3,884.89		3,884.89
2. Engine / generator room or building			3,850.15	19,542.58	23,392.73
3. Gas transport (boosters, blowers, pumps, piping, compressors, etc.)	17,566.00		50,920.96		50,920.96
4. Flare *(some flare costs also included in Line D3)*			2,420.20		2,420.20
5. Gas treatment (scrubber / cleaning system)					0.00
6. Controls, panels, meters and instrumentation (biogas & electricity)	2,310.00				0.00
7. Heat recovery (hot water; specify if other)					0.00
Subtotal	***238,606.00***	***0.00***	***196,638.20***	***19,542.58***	***216,180.78***
Section E. General Construction (not allocated in Sections B-D above)					
1. Excavation, trenching, and grading (including equipment usage)		579.97			579.97
2. Concrete work and materials					0.00
3. Electrical work and materials *Electrical work to connect generator to barn, wells, etc.*			2,359.11	29,759.92	32,119.03
4. Other contractor / subcontractor work (not already allocated)					0.00
5. Dairy labor used for construction and installation (if documented)					0.00
6. Transportation, fuel, and heavy equipment rental					0.00
7. Other equipment/materials *(storage container, required by RCM Digesters)*			2,143.37		2,143.37
Subtotal	***0.00***	***579.97***	***4,502.48***	***29,759.92***	***34,842.37***
1. Overall system design / engineering	45,000.00	60,321.16			60,321.16
Subtotal	***45,000.00***	***60,321.16***	***0.00***	***0.00***	***60,321.16***
1. Permits - air *($60 annual add-on fee for each engine)*	5,000.00				0.00
2. Permits - building *(rolled into contractor fees, included in Line D2)*				7,845.91	7,845.91
Subtotal	***5,000.00***	***0.00***	***0.00***	***7,845.91***	***7,845.91***
Section H. Utility Interconnection					
1. Interconnection permit and inspection process					0.00
2. Interconnection equipment required by utility (switch gear/relays, safety)			11,253.09		11,253.09
Subtotal	***0.00***	***0.00***	***11,253.09***	***0.00***	***11,253.09***
Section I. Other Associated Costs					
1. Overhead / administrative costs (describe):					0.00
2. Finance charge / capitalized interest (explain):					0.00
Subtotal	***0.00***	***0.00***	***0.00***	***0.00***	***0.00***
Section J. Total Costs Reported for this Grant					
TOTAL	**524,898.00**	**137,326.88**	**526,129.48**	**57,148.41**	**720,604.77**

Section K. Comprehensive System Costs to Date	
1. Initial costs incurred prior to this grant: *-Complete waste and rainwater management system in preparation of digester system, including: -A new lagoon, mixing chamber, pivots, and all associated pumps and electrical components*	**300,000.00**
2. Costs incurred after system completion (not included above)	**0.00**
TOTAL SYSTEM COSTS TO DATE	**1,020,604.77**

Summary of Costs, Project #226, Van Ommering Dairy

Section A. Project Information	
1. Dairy name	**#226-B, Van Ommering Dairy**
2. Purpose of grant	To install a new plug flow digester system
3. Total generator nameplate capacity	**130 kW**

Section B. Manure Collection and Pretreatment	**Estimated Costs**	**Actual Construction (Labor) Costs**	**Actual Equipment and Materials Costs**	**Equip/Mat'ls, LABOR INCLUDED**	**Total Actual Costs**
1. Lagoon constructed for biogas system					0.00
2. Lagoon liner					0.00
3. Manure collection (piping, pumps, electrical supply, etc.)	20,900.00		47,685.80		47,685.80
4. Vacuum trailer - *Loewen 2500 gallon capacity Honey-Vac*			38,884.00		38,884.00
5. Solids separator / grit removal	44,000.00		29,044.97		29,044.97
6. Collection mix tank	23,214.00				0.00
Subtotal	***88,114.00***	***0.00***	***115,614.77***	***0.00***	***115,614.77***
Section C. Digester and Gas Production Enhancements					
1. Digester / digester tank. **Plug flow digester volume: approx. 39, 424 ft^3 Dimensions: 30' wide x 130' long x 12' deep**	136,995.00		58,358.38	**259,786.89**	318,145.27
2. Lagoon cover system					0.00
3. Digester heating system			52,248.46		52,248.46
4. Bacterial treatment					0.00
Subtotal	***136,995.00***	***0.00***	***110,606.84***	***259,786.89***	***370,393.73***
Section D. Energy Conversion and Gas Handling					
1. Engine / generator *(genset purchased new)*	190,282.00		113,584.18		113,584.18
(a) One (1) CAT 3406 engine-generators, 130 kW capacity					0.00
(b) Engine / generator additional components *(generator piping)*			8,550.82		8,550.82
2. Engine / generator room or building			3,784.39	5,736.82	9,521.21
3. Gas transport (boosters, blowers, pumps, piping, compressors, etc.)	23,340.00		64,444.18		64,444.18
4. Flare *(cost included in Line D3)*					0.00
5. Gas treatment (scrubber / cleaning system)					0.00
6. Controls, panels, meters and instrumentation (biogas & electricity)	5,553.00				0.00
7. Heat recovery (hot water; specify if other)					0.00
Subtotal	***219,175.00***	***0.00***	***190,363.57***	***5,736.82***	***196,100.39***
Section E. General Construction (for work not allocated to Sections B-D above)					
1. Excavation, trenching, and grading (including equipment usage)		27,970.00	690.48		28,660.48
2. Concrete work and materials					0.00
3. Electrical work and materials				35,270.97	35,270.97
4. Other contractor / subcontractor work (not already allocated) *Water softening and conditioning*				922.08	922.08
5. Dairy labor used for construction and installation (if documented)					0.00
6. Transportation, fuel, and heavy equipment rental					0.00
7. Other equipment and materials (describe):					0.00
Subtotal	***0.00***	***27,970.00***	***690.48***	***36,193.05***	***64,853.53***
Section F. System Design and Engineering					
1. Overall system design / engineering	45,000.00	48,440.26			48,440.26
Subtotal	***45,000.00***	***48,440.26***	***0.00***	***0.00***	***48,440.26***
Section G. Permits					
1. Permits - air					0.00
2. Permits - building				2,000.00	2,000.00
3. Environmental Impact Report (EIR)				2,000.00	2,000.00
Subtotal	***0.00***	***0.00***	***0.00***	***4,000.00***	***4,000.00***
Section H. Utility Interconnection					
1. Interconnection permit and inspection process		4,750.00		32,684.86	37,434.86
2. Interconnection equipment required by utility (switch gear/relays, safety)					0.00
Subtotal	***0.00***	***4,750.00***	***0.00***	***32,684.86***	***37,434.86***
Section I. Other Associated Costs					
1. Overhead / administrative costs (describe):					0.00
2. Finance charge / capitalized interest (explain):					0.00
Subtotal	***0.00***	***0.00***	***0.00***	***0.00***	***0.00***
Section J. Total Costs Reported for this Grant					
TOTAL	**489,284.00**	**81,160.26**	**417,275.66**	**338,401.62**	**836,837.54**

Section K. Comprehensive System Costs to Date	
1. Initial costs incurred prior to this grant	**0.00**
2. Costs incurred after system completion (not included above) *-Installed an additional receiving tank*	**30,000.00**
TOTAL SYSTEM COSTS TO DATE	**866,837.54**

Summary of Costs, Project #248, Inland Empire Utilities Agency

Section A. Project Information					
1. Dairy name	**#248-I, Inland Empire Utilities Agency (IEUA) Regional Plant 5 Solids Handling Facility (RP-5)**				
2. Purpose of grant	To expand and modify an existing plug flow digester to become a modified mix plug flow digester (RP-5 Phase 1B Expansion)				
3. Total generator nameplate capacity	**Phase 1B Expansion = 563 kW** (Total capacity = 943 kW)				
Section B. Manure Collection and Pretreatment	**Estimated Costs**	**Actual Construction (Labor) Costs**	**Actual Equipment and Materials Costs**	**Equip/Mat'ls, LABOR INCLUDED**	**Total Actual Costs**
1. Lagoon constructed for biogas system					0.00
2. Lagoon liner					0.00
3. Manure collection (piping, pumps, electrical supply, etc.)	81,000.00		17,248.35		17,248.35
4. Vacuum trailer	200,000.00		438,097.20		438,097.20
5. Solids separator / grit removal	440,000.00	3,995.00	727,840.48		731,835.48
6. Collection mix tank			259,944.00		259,944.00
Subtotal	***721,000.00***	***3,995.00***	***1,443,130.03***	***0.00***	***1,447,125.03***
Section C. Digester and Gas Production Enhancements					
1. Digester / digester tank. **Plug flow digester total volume: 1,100,000 gal** **Dimensions: 60' wide x 195' long x 16' deep (vol = about 145,800 ft^3)** *Costs are for enhancements to existing plug flow digester.*	60,000.00			1,449,938.18	1,449,938.18
2. Lagoon cover system.					0.00
3. Digester heating system					0.00
4. Bacterial treatment					0.00
Subtotal	***60,000.00***	***0.00***	***0.00***	***1,449,938.18***	***1,449,938.18***
Section D. Energy Conversion and Gas Handling					
1. Engine / generator *(gensets were in place prior to this grant)*					0.00
(a) One (1) Waukesha 7042 engine-generator, 1000 kW capacity					0.00
One (1) Waukesha 5790 engine-generator, 850 kW capacity					0.00
2. Engine / generator room or building					0.00
3. Gas transport (boosters, blowers, pumps, piping, compressors, etc.)	210,000.00		22,611.24		22,611.24
4. Flare *(had an existing flare)*					0.00
5. Gas treatment (scrubber / cleaning system)	60,000.00				0.00
6. Controls, panels, meters and instrumentation (biogas & electricity)		4,000.00	65,983.11		69,983.11
7. Heat recovery (hot water; specify if other)					0.00
Subtotal	***270,000.00***	***4,000.00***	***88,594.35***	***0.00***	***92,594.35***
Section E. General Construction (for work not allocated to Sections B-D above)					
1. Excavation, trenching, and grading (including equipment usage)				200,875.00	200,875.00
2. Concrete work and materials		34,473.00			34,473.00
3. Electrical work and materials					0.00
4. Other contractor / subcontractor work (not already allocated)	424,350.00	23,415.07	2.54		23,417.61
5. IEUA staff labor used for construction and installation (if documented)		97,530.88			97,530.88
6. Transportation, fuel, and heavy equipment rental		13,131.19			13,131.19
7. Other equipment and materials *(misc. parts and materials)*			2,405.56	2,485.00	4,890.56
Subtotal	***424,350.00***	***168,550.14***	***2,408.10***	***203,360.00***	***374,318.24***
Section F. System Design and Engineering					
1. Overall system design / engineering	51,000.00	127,762.88			127,762.88
Subtotal	***51,000.00***	***127,762.88***	***0.00***	***0.00***	***127,762.88***
Section G. Permits					
1. Permits - air *(covered by Title V air permit for whole RP-5 facility)*					0.00
2. Permits - building		1,425.59			1,425.59
Subtotal	***0.00***	***1,425.59***	***0.00***	***0.00***	***1,425.59***
Section H. Utility Interconnection					
1. Interconnection permit and inspection process					0.00
2. Interconnection equipment required by utility (switch gear/relays, safety)			2,492.97		2,492.97
Subtotal	***0.00***	***0.00***	***2,492.97***	***0.00***	***2,492.97***
Section I. Other Associated Costs					
1. Overhead / administrative costs (describe):		51,246.28	4,544.97		55,791.25
2. Finance charge / capitalized interest (explain):					0.00
Subtotal	***0.00***	***51,246.28***	***4,544.97***	***0.00***	***55,791.25***
Section J. Total Costs Reported for this Grant					
TOTAL	**1,526,350.00**	**356,979.89**	**1,541,170.42**	**1,653,298.18**	**3,551,448.49**

Section K. Comprehensive System Costs to Date	
1. Initial costs incurred prior to Phase 1B expansion - *Construction of initial plug flow digester system at RP-5, including:* *-All digester equipment (e.g., piping, pumps, SARI capacity for flow/discharge, etc.). Does **not** include design or generators at Desalter.*	**9,400,000.00**
2. Costs incurred after system completion (not included above)	**0.00**
TOTAL SYSTEM COSTS TO DATE	**12,951,448.49**

10. Economic Performance

Estimated savings from generated power varied greatly between projects. The number of cows, biogas production, electrical production, and system performance all played an important role in determining the costs savings for each project. As discussed above, the use of the generated power, either on farm, net metering or a combination of both also played a vital role in the economic performance. Only a few of the projects benefited from savings due to the use of recovered heat or other revenue streams. A breakdown of estimated savings is detailed in Table 11 below.

As previously mentioned, not all projects are utilizing the generated power in the same fashion (i.e. on farm, net metering or a combination of both). Generally, those projects able to utilize the generated power on farm experienced greater estimated monthly savings. For the purpose of calculating estimated savings, the use of on farm power was valued at the energy rate portion of the total retail rate, not the full retail rate. This is due primarily to the fact that demand charges have not been reduced even though the total electricity purchased from the utility has been reduced substantially. Further, any net generation (occurring in periods where generation exceeds consumption) is valued at the generation rate of the full retail rate. A full discussion of this can be found in the Utility Issues and Net Metering Background and Overview section above. Additionally, any additional savings due to the use of recovered heat is noted. Finally, only one project, #248 IEUA reported additional revenue from other sources (tipping fees) during the study period.

Table 11. Estimated Monthly Savings

		Estimated Monthly Savings from Generated Power (based on savings during study period)						
			Net-Metering of Generated Power					
Dairy ID	Dairy Name	On-Farm Use of Generated Power	Average monthly net generation credits	Average monthly unbilled generation charges to which credits can be applied	Total Realized Savings from Generated Power	Recovered Heat	Other?	TOTAL ESTIMATED SAVINGS
Covered Lagoon Digesters								
#207	Blakes Landing	$1,523	$75	$3,333	$1,598	$300	$0	$1,898
#221	Castelanelli	$0	$4,371	$2,728	$2,728	$0	$0	$2,728
#204	Cottonwood	$13,233	$0	$0	$13,233	$7,000	$0	$20,233
#202	Hilarides	$10,476	$4,490	$1,734	$12,210	$0	$0	$12,210
#238	Lourenco	$0	$0	$0	$0	$0	$0	$0
Plug Flow Digesters								
#249	Eden-Vale	$0	$952	$734	$734	$0	$0	$734
#225	Koetsier	$2,057	$38	$0.35	$2,057	$0	$0	$2,057
#230	Meadowbrook	$3,727	$324	$864	$4,051	$0	$0	$4,051
#226	Van Ommering	$0	$2,175	$2,051	$2,051	$0	$0	$2,051
Modified Mix Plug Flow								
#248	IEUA-Phase 1B	$0	$0	$0	$0	$5,114	$1,550	$6,664

It should be noted that the estimated savings above are based on the study period for the individual project. Therefore, the estimated savings are not reflective of any recent developments or enhanced system performance. For instance, several projects were not running at expected capacity for the period examined. Upon reaching expected system performance, enhanced estimated savings from power generation will likely be achieved. Again, individual case studies should be referenced for a discussion of recent developments or planned changes that may aid in increasing estimated savings. Some examples include running the system at greater percentage of capacity or utilizing the power on farm instead of solely net metering. Changes such as these greatly alter the financial feasibility of the projects.

Estimated simple payback periods for the ten completed projects are listed in Table 12 below. As noted in the individual case studies, the simple payback estimate does not consider the time value of money, inflation or monthly operation and maintenance costs. The payback estimates are based on the estimated monthly savings listed in Table 11 above and the estimated cost of the project at completion. A payback estimated is calculated for both total costs without grant funding and total costs with grant funding. Any additional costs incurred after completion of the project or any maintenance or repair costs incurred after completion of the project are not included in the total project costs in the table below. These additional costs can be found in the individual case studies as well as in the individual cost summaries above.

Again, for a full understanding of all the factors behind the large variation in project costs, monthly savings and estimated payback periods, individual case studies as well as the previous sections should be referenced.

Table 12. Estimated Simple Payback Years

Dairy ID	Dairy Name	Estimated Total Cost at Completion	DPPP Grant	Other Grants	Out-of-Pocket Expenses	Estimated Simple Payback Years - Total Cost Without Grants	Estimated Simple Payback Years - Out-of-Pocket Expenses
Covered Lagoon Digesters							
#207	Blakes Landing (initial & refurbishment costs)	$334,680	$67,900	$87,361	$179,419	18.3	9.8
#221	Castelanelli	$882,136	$320,000	$227,396	$334,740	26.9	10.2
#204	Cottonwood	$2,498,038	$600,000	$240,000	$1,658,038	10.3	6.8
#202	Hilarides	$1,239,923	$500,000	$0	$739,923	8.5	5.1
#238	Lourenco (initial & refurbishment costs)	$372,912	$114,779	$0	$258,133	na	na
	Average	***$1,065,538***	***$320,536***	***$110,951***	***$634,050***	***16.0***	***8.0***
Plug Flow Digesters							
#249	Eden-Vale	$802,811	$300,000	$0	$502,811	70.3	44.0
#225	Koetsier (initial & refurbishment costs)	$1,361,087	$190,925	$0	$1,170,162	56.2	48.3
#230	Meadowbrook	$720,605	$262,449	$200,000	$258,156	14.8	5.3
#226	Van Ommering	$836,838	$244,642	$150,000	$442,196	34.0	18.0
	Average	***$930,335***	***$249,504***	***$87,500***	***$593,331***	***43.8***	***28.9***
Modified Mix Plug Flow							
#248	IEUA-Phase 1B (expansion only)	$3,551,448	$773,175	$175,000	$2,603,273	na	na

As previously mentioned, for the three refurbishment projects, #207, #238 and #230, total costs including initial costs and refurbishment costs are included for purposes of the analysis above. For #248, only the costs for the Phase 1B expansion are included. However, IEUA reported a rough estimate of $9.4 million in expenditures to construct the initial plug flow digester system at RP-5 prior to Phase 1B expansion. A payback period for #238 and #248 can not be determined as monthly savings attributable to power generation were not achieved during the study period. Again, the individual case studies should be referenced for a full discussion.

The dramatic increase in the payback years without grant funding compared to that with outside funding highlights the importance of grant funding to the financial feasibility of these projects. Even with substantial grant funding, due to the high costs of constructing the systems combined with the low economic returns for generated power, the simple payback period was longer than anticipated for most projects. Estimated simple payback periods with grant funding ranged from 5.1 years up to 48.3 years (increasing to a range of 8.5 to 70.3 without grant funding). For covered lagoon digesters, the payback period with grant funding ranged from 5.1 years up to 10.2 years. For plug flow digesters, the payback range with grant funding was 5.3 years to 48.3 years. Many factors influenced the payback estimates including, but not limited to, overall system costs, system performance and return for generated power. Also, as previously noted, the estimated savings are not reflective of any recent developments or enhanced system performance that took place after the study period. Again, individual case studies should be referenced for a full discussion.

11. System Performance and Environmental Testing

During the spring of 2006, a testing campaign was undertaken to collect baseline performance data on the digesters installed with funding from the Dairy Power Production Program. The objective of the testing was to characterize the manure influent and effluent for each system, measure the composition of the biogas, and test the emissions from the engine generator sets. Data was also collected to characterize manure solids separated before or after digestion.

The purpose of the data was to develop a one-time "snapshot" of the operating performance of each digester system, and this effort was not considered to be a comprehensive performance evaluation. A more comprehensive evaluation including an energy and mass balance on each system will require the same data to be collected over an annual cycle as there may be considerable temporal variability. If this endeavor is undertaken in the future, it is recommended that it follow a national evaluation standard developed for livestock waste digester testing.[16]

The data that was to be collected for each system was determined with input from the California Energy Commission, Western United Resource Development, and other interested parties. Attachment A shows the evaluation sheet that was developed and used as a guideline for data collection. Additional information was later determined to be important including composition of separated solids, concentration of dissolved solids in the influent and effluent, and a complete analysis of fixed gases in the biogas. The complete analysis included in the test campaign is discussed below.

Materials and Methods

This section describes the methods that were used at each site to characterize the dairy digester/power production systems.

Digester type, feeding, and inflow

The first objective at each dairy facility was to verify the design of the digester system including the sizing, feeding mode, and amount of flow to the digester. The area of the digester could be readily measured from the surface. The depth was verified with the dairy operator and the total volume was calculated.

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[16] Martin, J. H. 2006. *A Protocol for Quantifying and Reporting the Performance of Anaerobic Digestion Systems for Livestock Manures.* Report to Association of State Energy Research and Technology Transfer Institutions. DRAFT. April 2006.

Photo 1 A mechanical separator is used to remove solids from influent manure to covered lagoon digesters. Inflow samples were taken after separation. *Cottonwood Digester*

All digesters tested, both covered lagoon and plug flow, were fed intermittently either by timed operation of a flush system, delivery of scraped solids via a vacuum truck, or manual feeding from a collection/mixing basin. However, with the exception of Inland Empire Utilities Agency, none of the facilities consistently monitor or record the inflow or outflow from the digester. In order to determine the amount of inflow to the digester, information was collected from the dairy operators on the following: for covered lagoon systems, the number of flushes per day and estimated amount of water per flush; for plug-flow systems, number of loads of vacuumed manure delivered to the digester and the size of the loads. Using this data an estimate of digester inflow could be made and hydraulic retention time can be calculated. The estimate for the covered lagoon systems may be less reliable due to the lack of recycled water flow information for the flush systems. It was assumed that the amount of outflow is equal to inflow.

The composition of the manure inflow was measured via direct sampling at the most convenient point before digester entry. This point varied depending on the design of the handling equipment ahead of the digester. For the covered lagoon systems, there is a solids separation process ahead of the digester to remove bulky solids that generally have low digestibility and can clog the system (Photo 1). Samples were taken downstream of the solids separator or in some cases by sampling of the liquid effluent on the separator when no other open access was available. Five one-liter samples were taken at fifteen-minute intervals to follow the recommended spacing between sampling. Temperature and pH were determined using a handheld probe (Omega Engineering PHH 3X) for each one-liter sample. All sampling equipment was rinsed in the manure being sampled several times before collection of a sample and washed thoroughly between sites. The handheld pH meter was calibrated at each site using standard buffer solutions at pH 4.0, 6.0 and 10.0.

The first three samples were split evenly into three marked plastic containers for laboratory determination of COD and N, solids analysis, and VFA content. The analytes tested for are shown on Table 13. The last two samples were also split into two containers for an additional estimate of COD and N and solids analysis. A second sample for VFA determination was not collected due to the high cost of each test. Filled sample bottles were stored immediately on ice and were shipped in ice chests to the analytical laboratory via overnight courier.

For plug flow digester systems, samples could generally be collected directly from the mixing basin at the front of the digester (Photo 2), with the exception of one system where samples had to be collected directly from the vacuum truck as it unloaded (Photo 3). The same procedure of collecting five representative one-liter samples was followed. Samples were measured for temperature and pH and prepared for laboratory analysis in the same way described above.

Table 13. Analysis and Methods Used for Characterization of Inflow and Outflow Samples from Digester Systems.

Analyte	Units	MDL	RL	Method
COD	mg/L	0.2	0.5	4500
NH4-N	mg/L	0.7	1	4500
TKN	mg/L	4	5	5220C
TS	mg/L	10	10	2540C
VS	mg/L	10	10	2540E
TDS	mg/L	16.3	10	2540B
IDS	mg/L	16.3	10	2540E
TVFA	mg/L	20	20	5560C

COD = carbon oxygen demand; NH4-H = ammonia nitrogen content; TKN = total Kjeldahl nitrogen; TS = total solids; VS = volatile solids; TDS = total dissolved solids; IDS = inorganic dissolved solids; TVFA = total volatile fatty acids (as Acetic Acid); MDL = minimum detection limit of method; RL = minimum reporting limit of method; Method = Standard Methods for the Examination of Water and Wastewater, 19th ed., 1995.

Photo 2 Mixing basin at the head of a plug flow digester system where manure is delivered and samples were taken. *Meadowbrook Digester*

Digester outflow

Digester outflow was generally accessible and straightforward to sample. For covered lagoon systems, the digester outfall generally flowed to an adjacent storage pond for recycled flushing or irrigation (Photo 4). The outflow pipe could be sampled in the open storage pond using a sampling pole. For some systems the top of the outfall pipe was just below the water surface but a representative sample could be collected very close to the pipe opening. The sample collection and analysis procedure was identical to the inflow sampling.

The design of all of the plug flow systems with the exception of Inland Empire Utilities Agency included an outflow basin that continually filled with the outfall from the top of the digester (Photo 5). Sampling was straightforward and samples could be collected close to the digester outfall weir or pipe. Following the collection basin, the digestate was fed to a solids separator to separate the digested solids. In the case of Inland Empire, the digestate was pumped directly from the digester to rotary presses so sample containers had to be filled from a sampling port on the outflow pipe (Photo 6). The same sample handling and analysis was performed as described above.

Photo 3 A vacuum truck is used to remove solids from the housing area to the plug flow digesters. Inflow samples were taken directly from the vacuum truck for this facility because manure was fed directly to the digester with no mixing basin. *Koetsier Digester*

Separated solids

Each digester system incorporated some form of solids separation either before (in the case of covered lagoon systems) or after (in the case of plug flow systems) the digester. For covered lagoon systems, the purpose of solids separation is to reduce the amount of low digestibility solids (like bedding and undigested shells, chaff and straw from feed) and keep any foreign materials from entering the digester. These solids do not contribute much to biogas production and increase the rate of sludge and floating solids accumulation in the digester. Sloped screen separators (Photo 1) are generally used for this purpose, although one system made use of a settling basin before the covered lagoon (Photo 7). These solids are sometimes used for bedding or can be land applied.

Photo 4 Outfall from a covered lagoon digester system delivers digestate to a storage pond. Samples were taken close to the end of the outfall pipe. *Castelanelli Digester*

Photo 5 Outfall from a plug flow digester system goes to a collection basin. Samples were taken directly from outfall weir or pipe. *Eden-Vale Digester*

Photo 6 Outflow digestate is pumped directly to rotary presses, requiring sampling directly from pipes. *IEUA Digester*

Photo 7 A settling basin is used to separate solids before covered lagoon digester in one system. *Hilarides Digester*

Photo 8 A screw press separates solids from liquids after plug flow digestion so they can be removed and utilized as soil amendment. *Koetsier Digester*

Photo 9 Rotary presses are used to separate solids from polymer treated effluent. *IEUA Digester*

For a plug flow digester, the entire manure stream (without pre-solids separation) is fed into the digester to facilitate the plug flow action and mixing within the reactor. The only pre-treatment used for the plug flow systems is some mixing and sand settling in the collection basins or a coarse screening to remove foreign objects. However, the solids are separated from the liquids post-digestion to facilitate off-site removal. Screw press type solids separators are usually effective for this process and were common for the on-farm facilities (Photo 8). One facility (Inland Empire Utilities Agency) is using polymer coagulation and rotary presses to further reduce solids content of the digested liquid stream (Photo 9).

Digested solids are generally believed to be highly stabilized, possibly have a higher nutrient content and lower salt content than other solids, and valued as an organic soil amendment. It was determined that it would be useful to have a basic analysis of the composition of solids separated before and after digestion to help understand the value of these byproduct streams. Solids samples were taken directly from the solids separator and sealed in quart-size bags. The samples were immediately stored on ice and shipped with water samples to the analytical laboratory. Solids were analyzed for basic organic soil amendment properties as described in Table 14. The quantity or efficiency of separation was not determined as this would require more intensive sampling of the streams before and after the separator.

Photo 10 Biogas handling system with totalizing gas meter to record biogas production. *Eden-Vale Digester*

Table 14. Analysis Used for Characterization of Separated Solids from Digester Systems.

Analyte	Units
Moisture Content	%
Dry Matter	%
Ash	%
OM	%
C:N Ratio	
N	%
P	%
P_2O_5	%
K	%
K_2O	%
Na	%
Cl	%
Ca	%
Mg	%
Fe	mg/kg
Cu	mg/kg
Mn	mg/kg
Zn	mg/kg
S	%

Biogas production and quality

Each facility is metered with totalizing gas meters on biogas lines to quantify total biogas production delivered to the engine or flare (Photo 10). During this sampling campaign, gas flow rate to the engine was determined. To do this, the totalizer meter reading was recorded before and after each fifteen minute emissions test to estimate the flow rate of gas (in ft^3/min) to the engine. Most facilities record meter readings at periodic intervals and track gas production. These data sets are available and are more representative for showing the gas production of the systems over time.

Table 15. Analysis and Methods Used for Biogas Characterization.

Analyte	Units	MDL	Method
O_2	%	0.2	Fixed Gases EPA 3C
N_2	%	0.7	
CH_4	%	4	
CO_2	%	10	
CO	%	10	
H_2	%	16.3	
H_2S	ppm	16.3	ASTM D-5504

Samples of the biogas were also taken during the emissions tests to determine methane and carbon dioxide content, oxygen and nitrogen from introduced air, and hydrogen sulfide levels. Tedlar sampling bags (SKC 232-01, polypropylene valve, one-liter volume) were filled during two of the three emissions runs. Samples were generally taken as close to the engine as possible where a valve allowed for attachment and filling of the bag. All lines were purged before collecting the samples. Sample bags were labeled and immediately boxed for overnight shipping to the analysis laboratory. Samples were analyzed with the methods outlined in Table 15.

Emissions testing

Emissions from the biogas engines were determined during the digester testing campaign. A portable emissions analyzer (Testo 350XL, #01034445) was used for direct sampling of the exhaust stack (Photo 11). This instrument is accepted by the San Joaquin Valley Air Pollution Control District for in-field engine testing and is recognized for testing with US EPA methods CTM-030 and CTM-034. The unit employs electrochemical sensors for measuring O_2, NO, NO_2, CO, and SO_2, and hydrocarbons (as methane) and the sampling probe also measures stack temperature. The gas concentrations, temperature, and various other combustion parameters are also calculated and stored on the internal data logger.

Photo 11 Emissions testing equipment (covered to protect from sun) with sampling probe inserted in the exhaust stack of a biogas engine.
Eden-Vale Digester

The instrument was pre-calibrated at the factory immediately prior to use in the field and was re-calibrated every two weeks during the facility testing and re-checked at the end of testing. All calibration gases were NIST traceable and the factory calibration levels and instrument performance are shown on Table 16. The instrument remained stable with little drift for O_2, NO_x, CO, and SO_2 over the two-week period of testing. However the hydrocarbon sensor was not stable and therefore the hydrocarbon results are suspect and may not be reliable. Also, the zero for the O_2 sensor was not properly set during the first two-week period, but the data was corrected post sampling.

The sampling approach was to conduct three fifteen-minute runs (with 5-minute purge) at each facility to characterize the pollutant concentrations in the stack. The probe was generally inserted at least two diameters into the end of the stack for sampling. A few facilities had a sampling port in the stack that facilitated sampling. Gas concentrations were recorded once per minute for a total of fifteen samples for each fifteen minute average. All data was printed for a paper record and also downloaded to a PC for analysis.

Table 16. Instrument Performance and Calibration for Portable Emissions Testing Equipment Used for Biogas Engine Testing

Analyte	Units	Resolution	Accuracy*	Calibration Standard
O_2	%	0.1	0.2%	20.9 ± 0.2
CO	Ppm	1	10%	722 ± 36
NO_x	Ppm	1	10%	916 ± 46
SO_2	Ppm	1	10%	1018 ± 51
CxHy	Ppm	10	10%	10000 ± 500

*Accuracy is percentage of measured value and takes into account the instrument repeatability.

In order to convert concentrations to rate of emission (in lb/MMBtu), the following formula was used from EPA Method 19 as followed in Source Test Guidelines from the San Joaquin Valley Air District.[17]

$$E = \frac{C_p M}{385 * 10^6} F \frac{20.9}{(20.9 - \%O_2)}$$

where E is the emissions rate (lb/MMBtu), C_p is the dry concentration of the pollutant (ppm), M is the molecular weight of the pollutant, 385 is the standard volume of air at 68°F and 1 atm (dscf/lb), F is the oxygen based f-factor, dry basis for natural gas (8710 dscf/MMBtu), $\%O_2$ is the dry concentration of oxygen (%), and 20.9 is the concentration of oxygen in air (%).

This formula estimates the total amount of exhaust plus any excess air (as determined by the oxygen concentration in the stack) expected for complete combustion of a million Btu's of natural gas and multiplies it by the mass concentration of the pollutant. The use of this formula is an approximation, but it avoids the need to measure flow rate in a narrow, turbulent stack, which can lead to larger errors. The emissions rates for these engines can be directly compared to other engine emissions factors in the literature.

Results

The results for the study are discussed below. Average results for each facility can be seen in Tables 17-20 at the end of this section.

Digester inflow and outflow characteristics

The testing campaign collected representative one-day influent and effluent samples from each digester facility during April and May of 2006. Results for inflow and outflow characteristics for each digester tested are shown in Table 17. Averages for covered lagoon systems and plug flow systems are also shown to look for any statistical trends between inflow and outflow for the sample.

One caveat on the use of this data should be mentioned here. Because all of these systems are unmixed (or partially mixed in the case of IEUA's modified plug flow digester) and inflow can vary with time, it is difficult to make direct concentration comparisons between effluent and influent. Outflow samples actually represent digested manure that entered the system at an earlier date since the manure resides in the system for

[17] San Joaquin Valley Air Pollution Control District. 2002. *Source Test Guidelines.* July, 2002.

an average of one hydraulic retention time. Influent conditions may have been different at that time. As can be seen from Table 17, the solids concentration for the outflow is sometimes greater than the inflow, which wouldn't be expected in a system that reduces solids to form biogas. This is largely due to this temporal variability, which may be larger than the reduction produced in the digester. However, many other interesting observations can be made about the covered lagoon and plug flow digester systems tested.

For covered lagoon systems, the inflow total solids (TS) concentrations ranged from 0.24% to 1.36% with an average of 0.85%. The volatile portion of the total solids (VS) was low for several of the systems, ranging from 38%TS to 65%TS with an average of 53%TS, partially explained by higher inorganic dissolved solids (IDS), ranging from a high of 49%TS to a low of 27%TS for these systems. The high inorganic fraction is possibly coming from recycled wastewater used for flushing in these systems. In general, the systems that relied on recycled water had the high dissolved inorganics, low volatile solids results. From inflow to outflow, the covered lagoon systems showed a statistically significant ($\alpha = 0.10$) decrease in the volatile solids fraction (about a 16%TS decrease on average) and increase in inorganic dissolved solids fraction (about a 23%TS increase on average). This result would be expected in a system that reduces volatile solids.

Other constituents showed possible changes through the covered lagoon digestion process. The outflow chemical oxygen demand (COD) was lower for all of the systems (although the result was not statistically significant at $\alpha = 0.10$) ranging from 500 to 4,700 mg/L compared with an inflow COD ranging from 2,400 to 17,500 mg/L. The outflow total volatile fatty acid (TVFA) concentration were similarly lower ranging from 38 to 154 mg/L compared with inflow concentrations from 349 to 2890 mg/L. Changes in total Kjeldahl nitrogen (TKN) did not show a significant difference between inflow and outflow and ranged from 115 mg/L to 880 mg/L. Since nitrogen is conserved in the digestion process, this is an expected result. However, the amount of ammonia nitrogen (NH4-N) was significantly increased between inflow (ranging from 49 to 608) and outflow (ranging from 129 to 652). The pH of the inflow ranged from 6.2 to 8.2 but was in a more narrow range after digestion from 7.0 to 7.8. There was no major difference between influent and effluent temperatures as the covered lagoons are all unheated systems.

The plug flow systems are heated digesters designed for scraped or vacuumed manure at a much higher total solids concentrations. Inflow TS concentration for the systems tested ranged from 6.3% to 15.1% with an average of 10.8%. The volatile solids fraction was higher than for the covered lagoon systems, presumably because of the higher concentrations of manure and less contribution of dissolved solids and inorganics from recycled water. VS ranged from 67%TS to 78%TS with an average of 74.4%TS with IDS contributing only 7.5%TS to 13%TS with an average of 10%TS. While it is assumed that there is a reduction in volatile solids and an increase in inorganic dissolved solids during the digestion process in these systems, the samples taken did not show large differences between inflow and outflow VS, TDS or IDS concentrations.

Other differences between influent and effluent from the plug flow digesters are indications of active digestion. Both COD and TVFA were consistently lower in the outflow measurements compared with the inflow levels. The outflow COD ranged from 47000 to 78000 mg/L compared with levels of 67,000 to 133,000 mg/L in the inflow. The outflow TVFA ranged from 480 to 6,100 mg/L with inflow from 5,000 to 10,600 mg/L. Again there was no significant difference indicated between inflow and outflow total nitrogen with TKN ranging from 2,200 to 4,700 mg/L. Ammonia nitrogen ranged from 900 to 1,900 mg/L in the inflow with a range of 1,200 to 2,400 in the outflow. The pH of the inflow ranged from 6.6 to 8.4 in the inflow and 7.5 to 7.7 in the outflow. These heated digesters are designed to operate in the mesophilic temperature range and outflow temperatures ranged from 89°F to 98°F, higher than the inflow temperatures that are controlled by ambient conditions and ranged from 66°F to 84°F.

Separated solids characteristics

Separated solids were collected from three covered lagoon systems that used inclined screen separators before digestion (Photo 1) and four plug flow systems that pressed digester effluent to remove digested solids (Photo 8). Results can be seen in Table 18 that include the individual facility results and the averages for the two types of separation along with a statistical comparison. There were many significant differences in the composition of these byproducts from the two digester systems.

The moisture content of the solids from the inclined screens was generally higher averaging 85.5% wet basis compared with 74.4% wet basis for the screw press solids. This is probably due to the higher mechanical dewatering in the press. The pre-screened solids from the covered lagoons were also higher in organic matter (92.8% of dry matter) and than the post-separated solids from the plug flow digesters (78.8% of dry matter). Carbon nitrogen ratio was nearly double for the screened solids at an average of 38.4 compared with 23.4 for the digested solids, indicating higher nitrogen content post digestion. In terms of suitability as a soil amendment, the post-digested solids from the plug flow systems were higher in each nutrient with average nitrogen (N), phosphorous (P) and potassium (K) of 1.99%, 0.52% and 1.46% respectively compared with 1.44%, 0.20%, and 0.71% for the screened solids. In every other constituent measured, the digested solids were higher (double or greater) than the pre-screened solids.

Biogas quality

Biogas samples were taken from each digester system, typically near the engine during emissions testing. For two of the systems that employed sulfur scrubbing systems, samples were also taken before the scrubber. The results for each system can be seen in Table 19 along with a comparison of covered lagoon biogas and plug flow biogas.

In terms of fixed gases, the primary constituent of the biogas was methane (as expected) and ranged from 52.3% to 67.6% with an average around 60% for all of the systems tested. There did not appear to be a major difference between the total methane content in the covered lagoon biogas and the plug flow biogas. However, the carbon dioxide content of the covered lagoon biogas was lower at 29.2% compared with 37.4% for the plug flow systems. Therefore the methane to carbon dioxide ratio for the covered lagoon digesters was somewhat higher than the plug flow digesters. The lower levels of carbon dioxide in the covered lagoon systems was compensated with a higher amount of oxygen and nitrogen, presumably from air intrusion, with an average of 2.1% oxygen and 8.1% nitrogen in the biogas compared with only 0.6% oxygen and 1.7% nitrogen in the plug flow systems.

Interesting differences also existed in the hydrogen sulfide content of the biogas. There was a very large range of hydrogen sulfide concentrations in the post-digestion biogas ranging from a low of 4 ppm to a high of 1586 ppm. There is no single clear explanation for these large differences, but presumably the sulfur content of the manure and the biology of the digester make a difference. Covered lagoon systems had a statistically lower (a = 0.10) hydrogen sulfide concentration with a range of 4 ppm to 122 ppm with an average of 65 ppm. This compared with a range of 187 ppm to 1586 ppm for with an average of 718 ppm for the plug flow systems. Clearly, there needs to be more work in this area to understand how to improve the quality of the biogas, which is a critical issue for both engine performance and emissions.

The two sulfur scrubbers appeared to be effective at reducing hydrogen sulfide concentrations in the biogas. The reduction in sulfur content appeared to be greater than 90%.

Biogas engine emissions testing

Emissions data from biogas engine/generators were collected from all facilities and are summarized in Table 20. Engines were tested as they were operating, and air to fuel ratios, engine loading, fuel rate and other operating conditions were not altered during testing. For example, it was noted that several of the rich burn engines tested were being operated quite lean based on oxygen concentration in the exhaust, but there was no attempt to change this condition. Additionally, some engines were operating well below their rated capacity due to the level of biogas output. Also, for some engines, actual emissions levels could not be established due to the calibration limitations of the instrument. These factors make it difficult to formulate comparisons or draw long-term conclusions with this data. But it does give an indication of typical operating conditions in the field for some aggregate comparison with emissions factors.

Estimated emissions rates for carbon monoxide (CO) ranged from 0.37 lb/MMBtu to greater than 1.58 lb/MMBtu. This compares favorably with EPA emissions factors for natural gas engines, which are 0.56 for lean burn and 3.51 for rich burn engines running on natural gas.

Emissions rates for oxides of nitrogen (NOx) ranged from 0.03 lb/MMBtu to greater than 1.53 lb/MMBtu. The best performance came from engines that had some form of emissions control (catalyst or engine monitoring) to reduce this constituent. These results also compare favorably with EPA emissions factors for uncontrolled natural gas engines of 0.85 lb/MMBtu and 2.27 lb/MMBtu for lean and rich burn engines respectively.

Sulfur dioxide (SO_2) emissions rates ranged from 0.01 lb/MMBtu to 5.30 lb/MMBtu. The lowest results came from facilities with the lowest hydrogen sulfide in the biogas. However, hydrogen sulfide did not directly correlate with SO_2 concentration in the exhaust. These levels were higher than EPA emissions factors for natural gas engines (0.0006 lb/MMBtu), but typical natural gas has a very low sulfur content.

The hydrocarbon (C_xH_y) concentration in the biogas engine exhaust ranged from 0.24 lb/MMBtu to 11.79 lb/MMBtu. Due to the inability of the sensor used to hold its calibration during testing, some of these results may be unreliable. EPA emissions factors for hydrocarbons from natural gas engines are 1.47 lb/MMBtu for lean burn engines and 0.36 lb/MMBtu for rich burn engines.

Particulate matter (PM) emissions were not measured for these engines due to the high cost of this testing in-field, given the expected low concentrations in the exhaust. Typically direct PM emissions are not a major concern for gaseous fuels like natural gas and biogas, while they are a greater concern for liquid fuels like diesel that can have one hundred to one thousand times the emissions rate. US EPA emissions factors for PM from natural gas engines are 0.0001 lb/MMBtu for lean burn and 0.0095 lb/MMBtu for rich burn.

Photo 12 The outflow from this covered lagoon digester flows into an effluent vault. Electronic flow meter can be used to monitor flow rate. *Castelanelli Digester*

Photo 13 View directly into effluent vault where outflow samples were taken. *Castelanelli Digester*

Photo 14 Both inflow and outflow basins are located at the back end of this covered lagoon digester. In the foreground, manure is offloaded and mixed to be pumped to the far end entrance to the digester. In the background, effluent is delivered from the effluent basin to a rotary separator. *Van Ommering Digester*

Photo 15 View from the front end of the plug flow digester. Below are the control room (left) and engine room (right) and flare (upper left). Engine exhaust pipe can be seen out of the engine room with emissions testing equipment. *Van Ommering Digester*

Table 17. Measured Inflow and Outflow Characteristics from Digester Systems

Table 17. Measured inflow and outflow characteristics from digester systems

#	Date	Facility	Type	Flow	T	pH	TS	VS	TDS	IDS	COD	TVFA	TKN	NH_4-N
	2006				(°F)		(%)	(%TS)	(%TS)	(%TS)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
1	04/13	Castelanelli	Covered	In	67	7.7	1.09	38.6	44.3	31.0	9,942	349	883	608
1	04/13	Castelanelli	Covered	Out	67	7.8	1.43	37.8	56.6	43.7	13,802	73	1,152	652
2	04/18	Van Ommering	Plug	In	66	7.0	14.32	67.4	17.5	8.6	108,917	8,030	3,252	1,571
2	04/18	Van Ommering	Plug	Out	89	7.5	5.66	72.3	20.2	12.0	54,738	900	2,822	1,401
3	04/19	Meadowbrook	Plug	In	69	7.2	10.19	77.4	25.7	13.1	89,833	10,600	3,901	1,574
3	04/19	Meadowbrook	Plug	Out	98	7.7	8.37	71.1	22.6	14.7	62,371	615	3,617	2,234
4	04/20	IEUA	Plug	In	71	6.6	6.29	77.7	22.3	11.7	69,540	5,420	2,162	909
4	04/20	IEUA	Plug	Out	94	7.5	5.36	74.7	25.0	13.5	47,291	482	2,474	1,204
5	04/27	Blake's Landing	Covered	In	72	8.2	1.36	65.1	44.3	27.2	17,567	2,890	817	429
5	04/27	Blake's Landing	Covered	Out	67	7.3	0.69	46.3	61.5	48.7	4,657	161	626	511
6	05/01	Cottonwood	Covered	In	68	7.4	0.24	63.3	47.2	26.6	2,352	355	115	49
6	05/01	Cottonwood	Covered	Out	73	7.2	0.22	31.6	84.2	64.9	495	38	167	129
7	05/02	Koetsier	Plug	In	73	8.4	8.02	78.1	17.9	10.8	66,680	5,020	3,826	1,736
7	05/02	Koetsier	Plug	Out	86	7.5	8.16	75.7	14.3	10.0	68,251	2,440	3,843	1,716
8	05/02	Eden Vale	Plug	In	84	7.1	15.09	71.3	11.3	7.5	132,538	8,890	4,445	1,923
8	05/02	Eden Vale	Plug	Out	95	7.7	15.26	69.2	11.8	7.8	77,927	6,100	4,726	2,376
9	05/03	Hilarides	Covered	In	78	6.2	0.70	45.6	59.9	49.2	6,938	2,710	359	179
9	05/03	Hilarides	Covered	Out	74	7.0	0.49	32.0	80.3	68.6	1,500	184	284	175
*	All	Average	Covered	In	71	7.4	0.85	**53.2**	**48.9**	**33.5**	9,200	1,576	543	**316**
*	All	Average	Covered	Out	70	7.3	0.71	**36.9**	**70.6**	**56.5**	5,113	114	557	**367**
		p-value			*0.676*	*0.918*	*0.552*	***0.085***	***0.027***	***0.024***	*0.328*	*0.119*	*0.897*	***0.086***
*	All	Average	Plug	In	**73**	7.2	10.78	74.4	18.9	10.3	**93,501**	**7,592**	3,517	1,542
*	All	Average	Plug	Out	**92**	7.6	8.56	72.6	18.8	11.6	**62,115**	**2,107**	3,496	1,786
		p-value			***0.005***	*0.384*	*0.250*	*0.387*	*0.923*	*0.144*	***0.041***	***0.017***	*0.895*	*0.184*

Note: All facility results represent an average of two analyses from five aggregated samples.
*Statistically significant differences (α = 0.10) between inflow and outflow sample means for each digester type are shown in bold.

Table 18. Separated Solids Characteristics from Digester Systems

Table 18. Separated solids characteristics from digester systems

For covered lagoons, solids are removed by screening before digestion. For plug flow digesters, solids are removed by screw press after digestion.

#	Facility	Type	MC	DM	Ash	OM	C:N	N	P	P_2O_5	K	K_2O	Na	Cl	Ca	Mg	S	Fe	Cu	Mn	Zn
			(% wb)		(% dm)			---------------------------------------(% dm)---------------------------------------										-----------(mg/kg)-----------			
1	Castelanelli	Cover	87.1	12.9	8.3	91.7	36.5	1.46	0.21	0.49	0.85	1.03	0.17	0.22	0.63	0.21	0.18	806	99	66	108
5	Blake's Landing	Cover	84.3	15.7	8.7	91.3	31.2	1.70	0.24	0.55	0.87	1.05	0.16	0.35	0.49	0.26	0.17	1165	16	91	58
6	Cottonwood	Cover	85.2	14.8	4.6	95.4	47.4	1.17	0.14	0.31	0.40	0.49	0.15	0.33	0.45	0.11	0.17	709	15	48	52
2	Van Ommering	Plug	71.6	28.4	16.5	83.5	29.8	1.63	0.45	1.02	0.83	1.00	0.30	0.44	2.58	0.49	0.39	3258	75	104	157
3	Meadowbrook	Plug	80.8	19.2	20.6	79.4	20.7	2.23	0.70	1.60	2.12	2.55	0.59	0.65	2.12	0.84	0.40	2021	122	190	160
7	Koetsier	Plug	75.8	24.2	18.2	81.8	21.2	2.24	0.50	1.15	1.25	1.50	0.28	1.90	1.10	0.38	0.32	2541	48	97	138
8	Eden Vale	Plug	69.5	30.5	29.5	70.5	21.9	1.87	0.43	0.99	1.64	1.97	0.43	4.19	1.51	0.57	0.37	1814	116	170	179
*	Average	Cover	**85.5**	**14.5**	**7.2**	**92.8**	**38.4**	**1.44**	**0.20**	**0.45**	**0.71**	**0.86**	**0.16**	0.30	**0.52**	**0.19**	**0.17**	**893**	43	**68**	**72**
*	Average	Plug	**74.4**	**25.6**	**21.2**	**78.8**	**23.4**	**1.99**	**0.52**	**1.19**	**1.46**	**1.76**	**0.40**	1.80	**1.83**	**0.57**	**0.37**	**2408**	90	**140**	**158**
	p-value		***0.015***	***0.015***	***0.011***	***0.011***	***0.025***	***0.053***	***0.009***	***0.009***	***0.084***	***0.086***	***0.037***	*0.202*	***0.020***	***0.027***	***0.000***	***0.013***	*0.194*	***0.060***	***0.005***

*Statistically significant differences (α = 0.10) between covered lagoon and plug flow sample means are shown in bold. wb = wet basis. dm = dry matter.

Table 19. Biogas Composition as Generated from Digester Systems

Table 19. Biogas composition as generated from digester systems.

#	Facility	Type	Fixed Gases (%)[a]				H_2S (ppm)[b]	
			O_2	N_2	CH_4	CO_2	Post-dig.	Post-scrub.
1	Castelanelli	Cover	2.1	8.8	62.5	26.6	77	77
2	Van Ommering	Plug	0.3	0.5	67.6	31.6	301	301
3	Meadowbrook	Plug	0.7	2.3	58.7	38.3	1586	1586
4	IEUA	Plug	0.1	0.2	64.8	34.9	1228	64
5	Blake's Landing	Cover	2.4	11.3	64.5	21.8	4	4
6	Cottonwood	Cover	0.9	2.2	63.3	33.6	58*	0
7	Koetsier	Plug	0.9	2.8	55.7	40.6	187	187
8	Eden Vale	Plug	0.8	2.4	55.2	41.6	288	288
9	Hilarides	Cover	2.9	10.0	52.3	34.9	122	122
*	Average	Cover	**2.1**	**8.1**	60.7	**29.2**	**65**	-
*	Average	Plug	**0.6**	**1.7**	60.4	**37.4**	**718**	-
	p-value		***0.009***	***0.011***	*0.944*	***0.048***	***0.086***	

Note: Fixed gases are from average of two samples per facility. * may not be representative due to sampling location

* Statistically significant differences (α = 0.10) between covered lagoon and plug flow sample means are shown in bold.

[a] Fixed gases as percent total gas. H2 and CO were non-detect for all samples;
[b] For some facilities, sulfur scrubber was present and reduced H2S at engine.

Table 20. Emissions from Biogas Engines as Measured During Normal Operation on Digester Gas

Table 20. Emissions from biogas engines as measured during normal operation on digester gas

Emissions rates can be compared with US EPA emissions factors for natural gas, dual fuel, and large diesel stationary engines.

#	Date	Facility	Type	Flow	Tm	O_2	Measured Values (uncorrected)[c]				Estimated Emissions Rate[d]			
							CO	NO_x	SO_2	C_xH_y[e]	CO	NO_x	SO_2	C_xH_y[e]
				(cfm)	(°F)	(%)	------------(ppm)-----------				------------(lb/MMBtu)-----------			
1[a]	04/13	Castelanelli	Rich	-	823	3.2	-	>1374	-	-	-	>1.10	-	-
2	04/18	Van Ommering	Rich	21	252	10.1	>1083	56	50	15685	>1.33	0.07	0.14	11.04
3	04/19	Meadowbrook	Rich	68	804	0.6	566	1253	928	2381	0.37	0.88	1.39	0.89
4	04/20	IEUA	Lean	176	87	11.8	>1083	64	62	14169	>1.58	0.10	0.21	11.79
5	04/27	Blake's Landing	Lean	23	654	12.1	346	453	3	481	0.52	0.73	0.01	0.41
6[b]	05/01	Cottonwood	Rich	-	966	0.3	1,435	45	16	-	0.91	0.03	0.02	-
7	05/02	Koetsier	Rich	38	693	8.9	480	86	1328	2422	0.53	0.10	3.34	1.52
8	05/02	Eden Vale	Rich	19	641	14.1	589	129	1195	220	1.14	0.27	5.30	0.24
9	05/03	Hilarides	Rich	39	734	8.2	>1083	>1374	508	1518	>1.13	>1.53	1.21	0.90
							Digester Facility Average				*0.91*	*0.54*	*1.45*	*3.35*

	AP-42 Engine Emissions Factors[f]				
	CO	NO_x	SO_2[g]	C_xH_y	PM
	----------------(lb/MMBtu)--------------				
Natural Gas - Lean Burn	0.56	0.85	0.0006	1.47	0.0001
Natural Gas - Rich Burn	3.51	2.27	0.0006	0.36	0.0095
Dual Fuel (NG 95%, Diesel 5%)	1.16	2.70	0.895*S	0.80	-
Large Stationary Diesel	0.85	3.20	1.01*S	0.09	0.100

a. Instrument was unable to sample other analytes at this facility due to over limit on NOx sensor. Was tested at a later date with similar result.

b. Due to problems with catalyst compliance valve on sampling dates, certified data was provided by operator taken with similar instrument (without CxHy sensor).

c. Measurements greater than 150% of calibrated value are reported as >1.5*calibration. Unavailable data is left blank.

d. Emissions rate calculated as described in text.

e. CxHy results considered unreliable due sensor calibration failure over test period.

f. From US EPA. AP-42. Section 3: Large Stationary Combustion Sources. 10/96.

g. SO_2 emissions factor calculated from % sulfur content of fuel, S.

Individual Facility Discussion

A discussion of notable results from each facility is included below. Average results for each facility can be seen in Tables 17-20.

Project #221, Castelanelli Dairy

Digester inflow samples were taken directly from the effluent pipe on the solids separator. A sampling valve had been installed on a vertical pipe where separated effluent flows to the digester. Although the valve was purged before filling the sample bottle, it was noted that these inflow samples contained a significant amount of sand. This may have contributed to the low VS readings (38.6% TS) although a portion of this is explained by the high IDS (31.0% TS). As with several of the other covered lagoon systems, recycled water is used for flushing and contributes to the higher TDS and IDS content of this manure water. Outflow samples were taken from an effluent vault at the end of the digester (Photos 12 and 13). The inflow was about 1.09% total solids while the outflow was 1.43%. This may be partly due to recent increases in the amount of flushing at the facility. Other composition data can be seen on Table 17 and composition of the screened solids from separator are in Table 18.

Biogas was sampled from the gas handling system and contained about 11% air with a relatively low hydrogen sulfide concentration (77 ppm). An experimental biological scrubber had been installed on this system and may have impacted both of these results. The engine emissions proved difficult to measure at this facility due to a consistent over-limit reading on the NOx sensor. This could be due to high NOx levels or some other contaminant affecting this reading. Due to problems with super saturation of the electrochemical sensor, the equipment is designed to shut down and was unable to measure the other constituents in this situation.

Project #225, Van Ommering Dairy

This plug flow digester system has holding basins for both influent and effluent at the one end of the digester (Photo 14). Manure is delivered to a mixing basin where it is pumped to the head of the digester. Inflow samples were taken directly from this mixing basin. The outflow samples were taken directly from the effluent weir. The inflow manure was high in total solids (14.32%) compared with the TS of the digester outflow (5.66%) but the operator indicated that manure in the tank may have been thicker than usual. The VS concentration appeared to be in the normal range for manure, around 70%, with other inflow and outflow constituents shown in Table 17. Nutrient content of the soil amendment produced from this system is shown in Table 18. At the time of testing, the system was well below designed capacity awaiting the construction of new freestalls. This meant a higher than normal hydraulic retention time and lower biogas production. In addition, the digester temperature was below the desirable mesophilic range (as indicated by an effluent temperature of 89°F) from reduced gas to heat conversion.

The biogas from this system had the highest level of methane (67.6%) of all of the systems tested and a modest level of hydrogen sulfide (301 ppm) compared with other plug flow systems. The engine was tested directly from the end of the stack (Photo 15) and exhaust was fairly cool (252°F) due to a heat exchanger on the exhaust pipe used to heat water for the digester. The engine had relatively low levels of NOx production (0.07 lb/MMBtu) for a rich burn engine, although CO and hydrocarbons were higher. The engine was operating somewhat below its rated capacity at the time of testing due to the reduced gas production.

Photo 16 Vacuum truck unloads manure scraped from the dairy facility into a mixing/sand settling basin. Manure is mixed and allowed to settle overnight before pumping to digester to help settle sand picked up during vacuuming. *Meadowbrook Digester*

Photo 17 Engine room with gas handling and control equipment for digester engine. *Meadowbrook Digester*

Photo 18 Manure that has been picked up from local dairy facilities is offloaded into the digester. Manure is screened and mixed before it is pumped into the digester. *IEUA Digester*

Photo 19 View of hydrogen sulfide scrubber for gas cleanup. Gas is piped over 1 mile to desalination facility where engines are located. *IEUA Digester*

Project #230, Meadowbrook Dairy

This plug flow digester was operating at consistent capacity at the time of testing. Manure is vacuumed from the dairy lanes and delivered to a holding basin at the head of the digester (Photo 16 and Photo 2). This influent basin is filled and mixed during the daytime and is allowed to settle overnight to try to settle any sand that is picked up with the manure. The digester is fed once per day, in the morning, with the settled manure. The digested manure is also collected in a basin and pumped to a screw press separator. Samples of inflow and outflow manure were taken directly from the basins and a solids sample from the separator.

Inflow TS was 10.2% with 77.4% VS and 13.1% IDS and outflow TS was 8.4% with 71.1% VS and 14.7% IDS. Both COD and TVFA were reduced and NH4-N was increased between inflow and outflow. The digested solids were relatively high in N (2.23%), P (0.70%) and K (2.12%). Because this system had been operating consistently for some time before testing, these results are considered highly reliable.

Biogas from this system was about 58.7% methane and 38.3% carbon dioxide with a high level of hydrogen sulfide (1586 ppm). The operator indicated that the high level of sulfur had been a problem and that engine oil had to be changed very frequently to prevent corrosion (Photo 17). The engine emissions were somewhat higher in NOx (0.88 lb/MMBtu) and SO_2 emissions (1.39 lb/MMBtu) than other systems, but lower in CO and HC. Overall performance was good, but it is clear that reducing hydrogen sulfide in this system would be a benefit due to the increased cost of maintenance.

Project #248, Inland Empire Utilities Agency (IEUA)

This system was more intensively managed than the on-farm systems and had a higher level of equipment and regular monitoring. However, composition of the manure and biogas were typical of other plug-flow systems. Manure is delivered to the digester in full size container trucks that offload into a storage basin (Photo 18). Influent manure was sampled from the mixing basin after course screening. Outflow was sampled via a sample valve on the digester outflow pipes (Photo 6). Inflow TS was 6.29% with 77.7% VS and 11.7% IDS and outflow TS was 5.36% with 74.7% VS and 13.5% IDS. Both COD and TVFA were reduced and NH4-N was increased between inflow and outflow. Digested solids are typically separated using rotary presses and assisted by polymer addition to the effluent (Photo 9). This system was not operating during testing.

Photo 20 Lean burn engines that burn biogas from manure and municipal biogas from IEUA facilities. A controller optimizes engine performance and helps to minimize emissions. *IEUA Digester*

Biogas from the digester is sent to an iron sponge type scrubber (Photo 19) at the digester site. The digested biogas was high in hydrogen sulfide, 1228 ppm, which was reduced to 64 ppm after scrubbing. The manure biogas is piped nearly 1.5 miles where it is mixed with municipal biogas generated on another facility and delivered to one of the two (850 kW or 1,000 kW) lean burn engine-generators for electricity and heat production (Photo 20). The exhaust from these engines is continuously monitored to control air fuel ratio and NOx emissions. The portable emissions analyzer was attached to a second stack sampling line and was consistent with the results of the continuous on-line monitor.

Project #207, Blakes Landing Farms

This covered lagoon digester had several unique operating characteristics. First of all, manure is subject to two mechanical solids separators before digestion. The first separator is a screw press (Photo 21) that removes solids from flush water before it travels downhill to a holding tank. The manure is subject to a second rotary mechanical separator before it is delivered to the digester (Photo 22). The second unique characteristic is that the flushed manure is only about two-thirds of the direct feed to the system. A load of creamery wastewater is also directly fed to the digester once per day. Samples of the inflow manure and the creamery wastewater were taken directly from the holding tank. Outflow samples were taken at the far end of the digester near the outflow pipes where the cover was not secured (Photo 23). Table 17 shows the average composition of the combined inflow feed and the digester outflow. Measured separately, the inflow manure had a pH of 7.3 with 1.68 % TS at 66.6% VS and 25.2% IDS while the inflow creamery wash water had a pH of 9.1 with 0.72% TS at 54.6% VS and 42.2% IDS. The effluent was pH 7.3 with 0.69% TS at 46.3% VS and 48.7% IDS. The separated solids at the first separator appeared to be consistent with other pre-separated solids from inclined screens (See Table 18).

Photo 21 Manure flushed from freestalls is sent to a screw press separator to reduce solids before if flows downhill to a holding tank. *Blakes Landing Digester*

The biogas from this system had the highest amount of air (about 14%) and the lowest hydrogen sulfide (4 ppm) of the systems tested. The unsealed cover may contribute to the higher air intrusion but the cause of the exceptionally low hydrogen sulfide is unknown. It may have to do with some of the unique operating characteristics of this system and should be investigated further. The lean burn engine at this facility also showed low SO_2 emissions (0.01 lb/MMBtu) while other emissions appeared to be average for the systems tested.

Project #204, Cottonwood Dairy

This covered lagoon digester also utilizes processing wastewater, but it is first used for flushing instead of directly fed into the digester. The cheese plant wash water flushes the manure from the dairy instead of recycled pond water. The flush water is then screened (Photo 1) and delivered to the digester. An automatic sampler is installed in the system to collect aggregate samples of digester influent over an extended period (Photo 24). Inflow samples were taken from an aggregated sample that had been collected for the previous twelve hours. Outflow samples were taken near the effluent pipes in the adjacent storage pond (Photo 25). Inflow TS was 0.24% with 63.3% VS and 26.6% IDS and outflow TS was 0.22% with 31.6% VS and 64.9% IDS. Both COD and TVFA were reduced and NH4-N was increased between inflow and outflow. The solids concentrations were the lowest of all of the systems tested, in part be due to the use of the dilute wash water rather than recycled manure flush water as feed.

Photo 22 Manure from the holding tank is subjected to a second solids separator (middle of picture) before flowing to the digester (right). *Blakes Landing Digester*

Photo 23 Effluent flows through below-ground pipes at the end of digester to a lower holding pond. Samples were taken under cover near this exit pipe. The cover had been pulled up on far end of lagoon during windy conditions. *Blakes Landing Digester*

Photo 24 Automatic sampler for digester influent is used to take long-term aggregated samples at this facility. Inflow samples were taken using this system. Solids separator screen is seen in the background. *Cottonwood Digester*

Photo 25 Effluent from the covered lagoon digester (to the left of levee, out of picture) flows into a holding pond for irrigation. Outflow samples were taken using sampling pole near the end of these effluent pipes. *Cottonwood Digester*

Raw biogas from this digester appeared to be fairly low in hydrogen sulfide (58 ppm), however, this sample was collected directly from a pressure sensor port in the cover and may not be representative as the dairy's online sampler typically registers a higher hydrogen sulfide concentration. The biogas is then sent to a scrubber (Photo 26) to reduce it to below detectable levels before it is sent to the engine. Biogas was 63.3% methane and 33.6% carbon dioxide. The reason for the high level of scrubbing is to maintain the integrity of the catalyst used on this engine for reducing NOx emissions (Photo 27). This facility has strict restrictions for NOx emissions and the engine stack is routinely tested to verify proper operation of the emissions controls. During testing the compliance valve on the engine was in need of repair, so stack sampling was not possible.

The operator supplied recent test results using the same type of portable emissions analyzer, and this data is reported here (not including hydrocarbons which were unavailable). The catalyst appears to be effective at reducing emissions as this facility had the lowest NOx emissions (0.03 lb/MMBtu).

Photo 26 Biogas from the digester flows through this scrubber to remove hydrogen sulfide. Reducing the sulfur content of the fuel is needed to protect the catalyst used in the engine generator. *Cottonwood Digester*

Project #225, Koetsier Dairy

This refurbished plug-flow digester system uses vacuumed manure from the dairy that is delivered directly to the digester chamber without a mixing basin (Photo 3). Influent manure samples had to be taken directly from the vacuum truck during unloading. Outflow samples were readily taken in the effluent basin (Photo 28) where digested effluent collects before being delivered to the solids separator (Photo 8). Solids are collected and removed for soil amendment on a frequent basis. Inflow TS was 8.02% with 78.1% VS and 10.8% IDS and outflow TS was 8.16% with 75.7% VS and 10.0% IDS. The influent manure had an unexplained higher-than-normal pH of 8.4 compared with an average of 7.2 for the plug flow systems. The temperature of the effluent was 86°F, which is lower than expected, but effluent may have been somewhat cooled between the digester and the collection basin. The digested solids were relatively high in N (2.24%), P (0.50%), and K (1.25%).

The biogas was 55.7% methane and 40.6% carbon dioxide. It also had the lowest hydrogen sulfide level (187 ppm) of any of the plug flow systems. The emissions from the rich burn engine were tested from the top of the stack (Photo 29). The estimated NOx emission rate (0.10 lb/MMBtu) and CO emissions rate (0.53 lb/MMBtu) were among the lowest tested.

Photo 27 The biogas engine is located on the far side of the dairy from the digester. This power plant uses an exhaust heat exchanger (middle right) and catalytic converter (upper right) to remove heat and pollutants from the exhaust. *Cottonwood Digester*

Photo 28 Effluent from this plug flow digester (background) flows into a holding basin. Sample taken directly from end of effluent pipe. *Koetsier Digester*

Photo 29 Engine building is located next to the digester. Exhaust was monitored from the stack muffler exiting the building. *Koetsier Digester*

Photo 30 View from effluent end of this digester (as taken from the top of the solids separator structure) shows the extent of a typical plug flow digester. *Eden-Vale Digester*

Project #249, Eden-Vale Dairy

This plug flow digester system was very similar to several other systems with an influent and effluent basin (Photo 5) attached to a long-narrow digester (Photo 30) followed by a screw press type solids separator (Photo 31). Manure is collected from the dairy with a vacuum and delivered to the influent mixing basin at the head of the digester. Inflow samples were taken directly from this basin. Digested effluent falls from a weir at the end of the digester into the outflow basin where outflow samples were taken. The manure in this system was the thickest encountered during the testing, but still flowed through the system without problems. Inflow TS was 15.09% with 71.3% VS and 7.5% IDS and outflow TS was 15.26% with 69.2% VS and 7.8% IDS. COD and TVFA were reduced and NH4-N was increased between inflow and outflow. Outflow temperature was 95°F, in the mesophilic range. The separated solids were consistent with the other digested solids tested.

Photo 31 Screw press solids separator removes solids from the digester effluent. *Eden-Vale Digester*

Photo 32 Effluent is pumped from the settling ponds to the left into a header pipe under the cover of the primary digester. A pressure relief port is shown in the foreground where some inflow samples were taken. *Hilarides Digester*

Photo 33 Biogas is also produced from the second lagoon, generated under floating covers. *Hilarides Digester*

Photo 34 Digester gas is delivered to a series of four engine generators to produce electricity. Emissions were tested in the exhaust pipes at the top of the building. *Hilarides Digester*

The biogas from this system tested at 55.2% methane and 40.6% carbon dioxide. Hydrogen sulfide was on the lower end for plug flows at 288 ppm. The rich burn engine (Photo 10) appeared to operate normally, although the operator reported some recent problems that were being fixed. The emissions were measured directly from the stack (Photo 11) and were consistent with the other engines tested.

Project #202, Hilarides Dairy

This unique digester system includes a covered lagoon (Photo 32) followed by a partially covered storage pond (Photo 33) that digests flushed manure from a heifer ranch. The heifers are fed a different diet than mature milk cows including wet feed from food processing residues. Solids from flushed manure are separated using settling ponds (Photo 7) rather than with a screen or screw press as is typical on other facilities. Effluent from the settling ponds is directly pumped into the digester, which made it difficult to collect an undisturbed liquid sample. For this system one set of inflow samples was taken from the settling basin and another from the digester vent closest to the inflow distribution header on the digester (Photo 33). Outflow samples were taken where the digested effluent from the large covered lagoon was delivered to the adjacent storage pond. Some additional biogas is collected under floating covers (Photo 33) in this pond. Inflow TS was 0.70% with 45.6% VS and 49.2% IDS and outflow TS was 0.49% with 32.0% VS and 68.6% IDS. COD and TVFA were greatly reduced in the system. The pH of the influent collected in the settling basin was very low at 5.7 but had increased to 6.8 from the sample taken from the digester vent, stabilized by the lagoon while pH of the effluent was 7.0. Samples of the separated solids were not taken because they were not being removed from the basin at the time of testing.

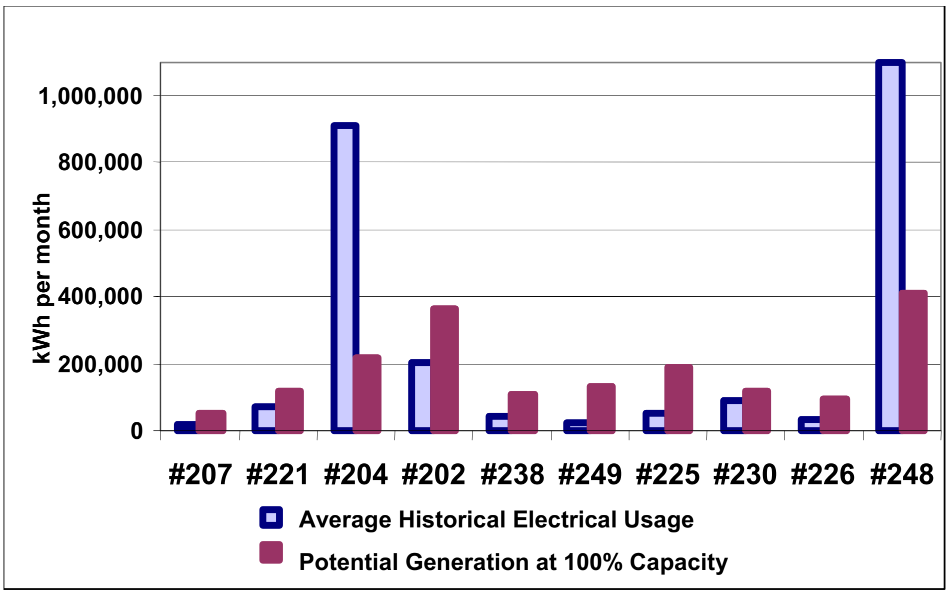
Biogas is generated from both covers and delivered nearly 1 mile to the engine generators at the adjacent dairy facility. Biogas was sampled at the engines and was high in air (about 13%) possibly from intrusion from the floating covers. Methane content was 52.3% with 34.9% carbon dioxide. Hydrogen sulfide content was 122 ppm, which was on the high end for the covered lagoon systems, but low overall. The system used a series of four rich burn engine-generators for producing electricity (Photo 34). Two of these engines were tested from the end of their stacks. The CO and NO_x were above the calibrated range for the portable analyzer, but the other constituents were in the sensitive range. Overall, the approach of using redundant smaller engines appeared to work well.

12. Program Benefits

Energy Production

Producing electricity from livestock wastes is a primary benefit of the program. In 2005, California had an estimated 2,043 dairies housing an estimated 1.76 million dairy cows. If biogas to electricity systems were installed at every California dairy, the systems would provide approximately 188 MW (or 188,320 kW) of generating capacity and over 1.6 billion kilowatt-hours per year of delivered electricity (assuming operation at 100% capacity).[18] The ten approved projects represent a generating capacity of nearly 2.5 MW and are capable of producing nearly 21.7 million kW hours per year of renewable electricity (assuming operation at 100% capacity).

Figure 6. Possible Electrical Generation Compared to Historical Electrical Usage, by project (kWh per month)



Power production from biogas at dairies is especially beneficial because it can help offset expensive peak electricity. Figure 6 shows the relationship between historical electricity use on farm and potential biogas electricity production on the completed projects. In most cases, the estimated amount of power available from biogas at the dairy exceeds the amount of power used at the dairy. This provides an opportunity for a dairy to offset on farm electrical costs, and, given the development of power purchase agreements, the financial feasibility could be greatly enhanced if excess power could be sold at a reasonable rate to the local utility company. This would result in not only helping the dairies economically, but could preserve electricity generated from fossil fuel-fired peaking units for consumers that have little or no capability to generate electricity.

[18] California Energy Commission, "Dairy Power Production Program-Supported by the California Energy Commission," page 1 of handout.

The historical usage for project #204 represents the usage for the on farm cheese plant where the generated power is utilized. The historical usage for project #248 represents the historical usage at the desalter facility where the generated power is utilized.

System Performance

Details on specific system performance can be found in the individual case studies as well as in the project comparison section above.

Each dairy owner or project manager was asked a series of qualitative questions to assess their overall satisfaction with the system. Each month, through monthly monitoring forms, dairy owners were asked to respond to the questions listed below. On a scale from one to four (with 1= poor and 4= excellent), the dairy owner was asked to rate his experience in a number of areas concerning the digester project. Individual project responses can be found in the case studies above. In looking at the projects as a whole, the following averages were obtained.

1. Ease in operating the biogas production and biogas to electricity systems 2.8
2. Extent to which system gives advantage to your dairy manure management 3.2
3. Extent to which the system helps with odor control 3.2
4. Extent to which the system helps with reducing water use for manure management 2.6
5. Extent to which system helps address electricity issues important to your dairy operation 2.7
6. Overall satisfaction with the system so far 3.1

Most categories scored an average score across projects. Extent to which the system helped with reducing water usage and extent to which system helped address electrical needs received the lowest scores. Extent to which the system helped with manure management and odor control received the highest scores across all projects. Overall satisfaction with the projects received an average score of 3.1.

Economic Performance

As previously mentioned, in most cases the potential existed for generated electricity to offset most or all of the electricity usage on the dairy. According to the California Department of Food and Agriculture figures, utility costs represented approximately 2% of the total cost of production for a California dairy in 2005.[19] This equated to $4.45 per cow per month of the total $239 per cow per month cost of production. Though utility costs are not a large portion of total production costs, the offset of these costs can be beneficial. This is particularly true given the regulated pricing structure innate to the California dairy industry that governs the minimum price paid to producers for their raw milk. The pricing system is too complex and cumbersome to explain here, however, it should be noted that it is essential for dairy producers to strive to reduce production costs in order to remain viable. This is especially true for the current period when producers are facing historically high production costs in conjunction with historically low milk prices.

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[19] California Department of Food and Agriculture, Division of Marketing Services, Dairy Marketing Branch, “California Cost of Production 2005 Annual,” page10.

Though the construction of a methane digester system and subsequent potential to generate electricity does provide a mechanism to lower overall production costs, it must also be recognized that a rather large capital investment is needed to build a digester system. As noted, among the ten completed projects, the cost for a covered lagoon digester averaged $1,065,538 and the cost for a plug flow digester averaged $930,335. The one modified mix plug flow expansion cost $3,551,448.

The financial feasibility of the completed projects varied greatly depending on the capital costs associated with building the system and the estimated savings attributable to the generation of power, use of recovered heat, or other resulting revenue streams. Again, as outlined several times previously, savings attributable to generated power varied greatly depending on the way the power was utilized (i.e. either on farm, net metered or a combination of both) and overall system performance. Even though use of generated power on farm proved to return the greatest estimated savings, the fact that demand charges were not subsequently reduced greatly lowered the potential savings from the use of generated power on farm. Also, the lack of economic incentives (primarily due to the lack of power purchase agreements) resulted in many of the projects operating at less than full generating capacity and greatly increased the payback period. In most cases, the potential existed for the production of excess electricity; however the benefit was not realized due to the lack of compensation for the power. In many cases, the cost to run the system at full capacity outweighed the incentives to produce the energy.

Savings due to generated power, use of recovered heat or other revenue streams did occur for most all of the projects. However, with the large capital costs needed to build the digester systems combined with the rather low savings, payback periods exceeded original estimates. For the ten completed projects, simple estimated payback periods with grant funding ranged from 5.1 years up to 48.3 years (increasing to a range of 8.5 to 70.3 without grant funding). For covered lagoon digesters, the payback period with grant funding ranged from 5.1 years up to 10.2 years. For plug flow digesters, the payback range with grant funding was 5.3 years to 48.3 years.

Additional grant funding, power purchase agreements at competitive rates or other revenue streams will be needed in order to generate renewed interest for dairy owners to build more digester systems at such large capital investments in California.

Cost Savings and Revenue Generation

Due to the unique characteristics of each project estimated monthly savings varied greatly. A full discussion of monthly costs savings attributable to the generation of electricity can be referenced above. Estimated monthly savings ranged from as little as zero during the study period up to $20,000 per month depending on the utilization of power and if additional revenues were generated due to the use of recovered heat, sale of byproducts, etc.

In addition to savings explored above, there are other potential revenue streams that have been mentioned or plans to implement them are underway. A rather large revenue stream for currently operating methane digester projects across the nation have come from the ability to sell excess generated power back to the utility company. In California, this has not been a viable option for the completed projects due to utility deregulation and the utilities reluctance to support distributed generation up to this point. However, as previously mentioned, discussions are taking place with utility companies to implement power purchase agreements for these projects. Though plans are still in the preliminary stages, it does look as though power purchase agreements could be available in the near future. It will be important that these power purchase agreements are offered at competitive rates that exceed those already realized by the offset of power usage on farm.

Other possible offset costs or revenue streams may come from the utilization of biogas for heating or cooling purposes or from the sale of byproducts. Several of the projects have reported savings due to the use of recovered heat however none have sold their digested solids as byproducts thus far. Several dairy owners have expressed their intent to research the possibility.

Another potential revenue stream is through the sale of environmental attributes or carbon credits. Project #204, Cottonwood Dairy recently made their first sale of carbon credits on the Chicago Climate Exchange (CCE). Project #225, Koetsier Dairy has recently applied to the CCE but has not yet made a sale. The project manager at Cottonwood Dairy reports that the process of getting signed up with the CCE was cumbersome and involved some up-front costs (approximately $1,000 to sign up, $1,000 per year, and $3,000-$4,000 for a verifier). However, it is estimated that the sale will result in monthly savings of approximately $8,333 per month or $100,000 per year. Additionally, rather than selling directly to the CCE, it is also possible to contract with an aggregator. Aggregators usually charge a fee based on a percentage. Recent ads from companies such as AgRefresh advertise a potential payment of $0.05 to $0.07 per kilowatt hour for non-energy attributes.

According to a recent PIER report, Federal Production Tax Credits (PTC) could be available to these projects. However, according to the report, "…unless they involve a third party owner, will apply only to the portion of the energy that is exported. It appears that under the Energy Policy Act of 2005 that the PTC rates can be reduced as a result of funding received from sources like the USDA."[20]

[20] Competitive Energy Insight, Inc., Prepared for the California Energy Commission Public Interest Energy Research Program (PIER), "Evaluation of Policy Impacts on the Economic Viability of California-Based Combined Heat and Power from a Project Owner's Perspective," July 2006, page 19.

13. Lessons Learned and Suggestions for Improvements

A long list of suggestions for improvements and individual lessons learned were provided by the dairy owners and/or project managers. Individual responses can be found in the detailed case studies. The list includes, but is not limited to the following:

- Lack of power purchase agreements for generated power reduced economic feasibility
- Establish better communication with utility company
- Install larger engine-generator
- Connect electric load directly to engine-generator
- Ran system at less than capacity due to little to no compensation for excess generated electricity
- Consider all alternatives carefully before moving ahead
- Make sure all economics of project work and challenge all assumptions
- Check out all contractors, equipment and service providers carefully
- Assume there will be significant cost overruns and time delays
- Apply for all permits and electrical interconnects early and stay on top of processes
- Grants and subsidies are important
- Keep system simple and user friendly
- Costs to run engine-generators are not currently offset by benefits of producing power for net metering purposes
- Operational expenses are higher than anticipated and electrical generation value is much lower
- Provide adequate training on machinery for staff
- System is designed to work as a whole and efficiency of the entire system can be affected by a small problem in one of the components
- A simplified control system for engine-generator would be preferred
- Need to process input material better to remove sand and foreign objects before pumping into digester
- Difficulty in interpreting utility company's method of net metering and monthly bills; and
- Some significant time delays on billing issues with utility company caused confusion.

14. Methodology

Data Collection

Monthly Monitoring

Upon project completion, monthly monitoring forms as well as electrical and biogas meter logs were submitted by each grant recipient. In addition, utility bills (including monthly bills as well as net metering bills) were collected and analyzed monthly. Each quarter, grant recipients were asked to complete status reports to document project progression.

System Performance and Environmental Testing

During the spring of 2006, a testing campaign was undertaken to collect baseline performance data on the completed projects. The objective of the testing was to characterize the manure influent and effluent for each system, measure the composition of the biogas, and test the emissions from the engine-generator sets. Data was also collected to characterize manure solids separated before or after digestion.

The purpose of the data was to develop a one-time "snapshot" of the operating performance of each digester system, and this effort was not considered to be a comprehensive performance evaluation. A more comprehensive evaluation including an energy and mass balance on each system will require the same data to be collected over an annual cycle as there may be considerable temporal variability

The data that was to be collected for each system was determined with input from the California Energy Commission, Western United Resource Development, and other interested parties. Please see the *System Performance and Environmental Testing* section of this report for a full discussion of testing materials and methods used.

Calculating Savings from Generated Electricity

Savings can come from two sources:

1. Offset of on-farm usage (if applicable)
2. Any net generation credits accrued (if applicable) under net metering provisions. Only those generation credits that can be applied towards unbilled generation charges on the other dairy accounts included in the net metering billing can be included in actual realized savings. Otherwise, these credits are zeroed out at the end of the 12-month tracking period. The utility is not required to provide compensation for these excess credits (see full discussion in utility section above).

Each dairy provides metered electrical generation figures by month. For those projects whose main load is connected to the engine-generator (i.e. generated power is used on farm and surplus is sent to the grid), estimated savings are calculated by the following formula:

Utility Savings = ((Metered electrical production – net electrical generation) * Energy rate) + net electrical generation * Generation rate))

For those dairies not using the generated power on farm, their savings are simply their accrued generation credits up to the level at which they are able to use them towards paying their unbilled generation charges.